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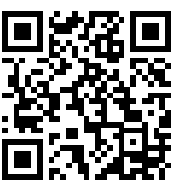

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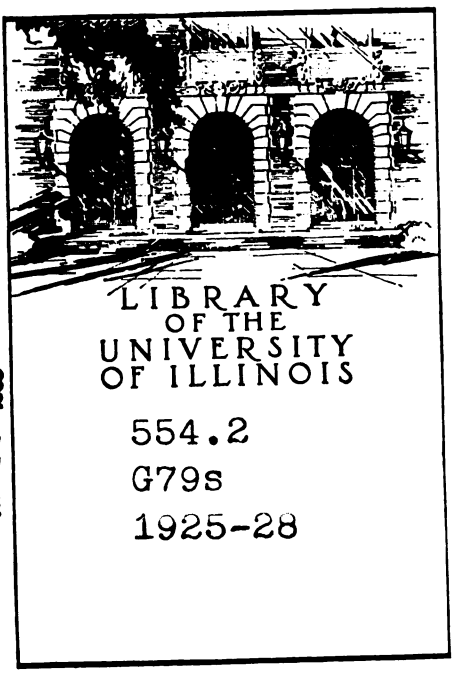
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Department of Scientific and Industrial Research

Summary of Progress

of the

Geological Survey of Great Britain

and the

Museum of Practical Geology

for the Year 1925

With Report of the
Geological Survey Board and
Report of the Director

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* PROFESSOR BOULTON, PROFESSOR GREGORY and MR. MERRICKS retired from the Board at the termination of their period of appointment on 31st December, 1925. PROFESSOR T. J. JEHU, M.A., M.D., MR. HUMPHREY M. MORGANS, B.Sc., and PRINCIPAL T. FRANKLIN SIBLY, D.Sc., were appointed members of the Board from 1st January, 1926.

DEPARTMENT OF SCIENTIFIC AND INDUSTRIAL RESEARCH,
16, Old Queen Street,
Westminster, London, S.W. 1.

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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1925

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Sixth Annual Report on the work of the Survey and Museum.

1. We are in a position to report that, but for one vacancy in the grade of geologist, the authorised strength of the Geological Survey and Museum staff has been maintained throughout the year, and that the full programme of work has been carried out. The Report of the Director, with the details of the work and publications of the Survey in 1925 which it embodies, shows that the enlarged staff of the Survey is now fully effective, and that due provision is made alike for carrying out the pre-arranged programme of survey and for meeting the frequent unforeseen calls for investigation.

2. We mentioned in last year's Report the retirement on 3rd January, 1925, of Dr. Walcot Gibson, F.R.S., who had been Assistant to the Director, and in charge of the work of the Survey in Scotland since October, 1920. On 5th January, 1925, Mr. Murray Macgregor, who had for four years supervised the geological work in the Central Coalfield of Scotland and in the North-eastern Highlands, was promoted to the post rendered vacant by Dr. Gibson's retirement.

We must in this Report refer to the death of Mr. William Whitaker, F.R.S., on the 15th January, 1925, for although at the time of his death he had left the staff for nearly thirty years, he had been during much of that time an active worker on behalf of the Survey. Born in 1836, he joined the staff as an Assistant Geologist in 1857, became Geologist in 1863, and District Surveyor in 1882. In addition to the exceptionally large series of maps and memoirs of which he was the sole or joint author, he published many important papers in geological journals or in the transactions of local scientific societies. He thus made many original advances in the general principles of geology as well as applying such principles to promote a detailed knowledge of the geology of the country. He retired in 1896. He had then an extensive knowledge of the geology of England, and wide experience of its bearings on water-supply, which fitted him in a marked degree for the work of preparing Survey memoirs dealing with water-supply. Accordingly, after his official retirement and until within a few months of his death, his services were largely utilised in the preparation of these memoirs. His critical analysis of the available records and his correlation of these with one another and with the ascertained facts of geological structure contributed greatly to the value of the published memoirs.

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3. The allocations of the Field Units engaged on surveys of the districts described by the programme for the year were as follows :—

(*a*) London and South Eastern District (primary six-inch survey).
(*b*) Midland District (primary six-inch survey).
(*c*) Yorkshire District (revision of six-inch survey).
(*d*) Lancashire District (revision of six-inch survey).
(*e*) Cumberland District (revision of six-inch survey).
(*f*) Northumberland and Durham District (revision of six-inch survey).
(*g*) Ayrshire District (revision of six-inch survey).
(*h*) Lanarkshire, Ayrshire and Peeblesshire District (revision of six-inch survey).
(*i*) Fifeshire (with Kinross) District (revision of six-inch survey).

The several Field Units have worked as in the previous year in direct connection with the Branch Offices of the Survey at Newcastle-on-Tyne, Whitehaven, Manchester and York. Similarly the Newcastle-on-Tyne Office continued to work under the Assistant to the Director in Edinburgh, and the others under the Assistant to the Director in London.

Details of the work carried out by each of the Field Units will be found in the Director's Report and in the 'Summary of Progress.'

4. As the above statement indicates, the chief feature of the field work of the Survey during the year has again been the prosecution of the primary six-inch survey of two important areas not previously surveyed on that scale and the revision of those coalfield areas originally surveyed on the six-inch scale more than thirty years ago but not since re-examined. The temporary suspension of the primary six-inch survey of the Highlands of Scotland has been maintained throughout 1925 with a view to greater concentration on coalfield work in Scotland.

In the course of the year we were pleased to find that this concentration had already secured sufficient progress in the coalfield work to justify the partial resumption of the primary six-inch survey of the Highlands and, as Your Lordships have approved the recommendation to that effect, it is hoped that work will be resumed in the North Highlands of Scotland for some part of 1926.

With regard to the Survey's indoor work, it is gratifying to note the progress made in clearing off the arrears in publication of One-inch maps and Sheet explanations relating to areas surveyed in the main prior to the rearrangements of the staff in 1921 and 1923.

5. Substantial progress, too, has been made in dealing with the accumulated arrears of publication of water-supply memoirs. Reports relating to the counties of Wiltshire and Dorsetshire had been prepared in 1923 by the late William Whitaker, but the high cost of printing prevailing in the last few years had rendered

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immediate publication inadvisable. The decision, mentioned in last year's Report, to publish the water-supply memoirs in a condensed form has been put into operation for these two counties. The data previously got together by Mr. Whitaker were revised, and a good deal of new information was incorporated. The most important of the borings and wells were visited with a view to verifying the sites and records so far as possible. In the cases of some of the older records, which from their lack of detail could no longer be fully interpreted, efforts were made to include only such information as was reliable and of sufficient importance. The memoir on Wiltshire was published at the end of 1925, and that on Dorsetshire was in the press.

In order to get the fullest information possible for this class of economic memoir the assistance of an outside expert, Mr. Linsdall Richardson, has been utilised in preparing water-supply memoirs on certain counties with which he is especially well acquainted. In addition to the memoir on the county of Gloucestershire (reported in 1923), memoirs on the water-supply of Worcestershire, Warwickshire, and Somerset have now been prepared by him and await publication.

Numerous enquiries continue to be received from members of the public as to water prospects in the South-east of England and the Midlands. With a view to keeping the published information up to date, steps are being taken to prepare for publication the latest records of the London District and of Sussex, of which there are many in manuscript in the Survey Office.

6. As in previous years the Survey has, for the writing of certain explanatory sheet memoirs, again availed itself of the professional assistance of geologists outside the Survey who are possessed of special knowledge of certain areas. For example, Mr. Osborne White has written the memoir on the Lewes Sheet, and is now engaged on a volume explanatory of the Hastings and Dungeness Sheets. Professor P. G. H. Boswell, too, has completed a memoir on the Ipswich Sheet and is now at work on one relating to the Felixstowe and Woodbridge area. Dr. W. Gibson's services, after his retirement, were also utilised in the preparation of a third edition of the Stoke-on-Trent memoir.

7. It is with satisfaction that we record the publication of the first volume in six parts of the late Dr. Kidston's monograph on the Fossil Plants of the Carboniferous Rocks of Great Britain. This volume, which gives an authoritative account of nearly all the ferns and fern-like plants, comprises all that was actually finished by Dr. Kidston. Material for the continuation of this work was prepared by Dr. Kidston before his death, but some time must elapse before further parts can be completed.

8. The Survey has continued its work on the useful series of Special Reports dealing with the mineral resources of Great Britain.

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During 1925 two new volumes have appeared. A second edition of one of the earlier iron-ore reports (Volume VIII) was also published. Another of the iron-ore reports (Volume X) has recently been reported as out of print, and steps are being taken to prepare a new edition of it.

Of economic memoirs not included in the 'Special Report series,' two, viz.—'The Concealed Coalfield of Yorkshire and Nottinghamshire' and 'The Oil Shales of the Lothians,' have been reported as sold out; new editions of these have been prepared and are now passing through the press.

9. We have devoted considerable attention to the question of the detection of underground deposits by gravitational means. Advantage was taken of the kindness of the Anglo-Persian Oil Company, Ltd., to attend a conference in London, at which a description of the geophysical survey carried out by that Company with the Torsion Balance in Persia during 1924–25 was given. The fullest information as to the methods of investigation used and the results achieved was placed at our disposal. We are of opinion that the evidence for this method of location has been so well established for some cases that its further application should be carefully considered and tested.

We consider, however, that before urging the desirability of providing the opportunity in this country for a suitable test of the possibilities of the methods it would be well to await the results of the applications of the gravity survey by the Anglo-Persian Oil Company in Persia during the season of 1925–26. These results are expected to be available in the summer of 1926.

10. With a view to assisting agriculturists interested in soil research and soil mapping, a conference between officers of the Geological Survey and members of the staffs of university departments of agriculture and agricultural colleges who are engaged in a special study of soil questions was held in the course of the year. As arranged at this conference, each of seven selected areas was surveyed by a geologist and a soil expert working in concert in order to ascertain the relations between geological drift mapping and the distribution of soil types. Efforts are now being made to record particulars of the soil by means of a scheme of lettering on the six-inch scale drift maps of the selected areas in addition to the usual details of the surface geology. It is hoped that a plan will be devised by which it will be possible to render the Geological Survey maps of greater help to the agriculturist in the future than has been possible in the past.

11. We have pleasure in recording that as from the 4th August, 1925, the Museum of Practical Geology was re-opened to the public after having been closed since April, 1923. The roof has been shored up with wood scaffolding, and certain conditions as to the loading of galleries and floors were enforced. So far as possible the scaffolding had been screened off, and the screens were utilised for

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the exhibition of maps and photographs. The erection of the scaffolding reduced the exhibition space, so that twenty cases of exhibits had to be dismantled and the specimens transferred to store. The re-opening of the Museum, even thus maimed, was much appreciated both by those who came to make specific enquiries and by students.

12. We noted that financial provision was made in the Office of Works' Estimates for 1925–26 for the preliminary work in connection with the erection of the new Geological Survey and Museum building at South Kensington.

In view of the 'uncertain' and 'crippled' condition of the present Jermyn Street building we venture to express the hope that all possible progress will be made with the provision of the new building at South Kensington.

13. The programme of field work for 1926 is :—

(*a*) London, Midland districts of England, and North Highlands of Scotland: continuation of the primary six-inch survey, and minor revisions in the Hastings, Dungeness, Ipswich and Woodbridge Sheets.

(*b*) Revision of the primary six-inch survey of Northumberland, Durham, Cumberland, Lancashire, Yorkshire, Ayrshire, Lanarkshire, Fifeshire (with Kinross).

(*c*) Continuation of investigation of underground water supplies and collection of records of borings with examination of specimens from them. Investigation of mineral resources.

F. G. OGILVIE,

30th April, 1926. *Chairman.*

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REPORT OF THE DIRECTOR OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1925

DR. WALCOT GIBSON retired from the service on 3rd January, 1925, and Mr. Murray Macgregor was selected to succeed him as Assistant to the Director in charge of the Survey's work in Scotland and Northumberland as from the 5th January. Dr. Gibson had for many years been engaged principally in the mapping of Carboniferous districts and the preparation and editing of the descriptive memoirs of certain English coalfields. In 1920 he was transferred to Edinburgh, where his ripe knowledge of coalfield geology and his sound judgment on economic problems enabled him to render great service to the Survey and maintain the high standard of our economic investigations. The mapping of the coalfields of Scotland has been very actively prosecuted during the last five years, and we are now in sight of the completion of the first revision of the Scottish Carboniferous strata on the six-inch scale. Dr. Gibson devoted himself with enthusiasm to this work and its rapid progress is in no small measure due to his skilful management.

Mr. J. E. Richey, M.C., B.A., has been appointed to the vacancy in the ranks of District Geologists created by the promotion of Mr. Murray Macgregor, and has taken charge of the revision of the Central Coalfield of Scotland with the outlying areas of Muirkirk and Douglas, which still remain to be revised. He has also started the re-survey of the south end of the Midlothian Coalfield, previously revised by Dr. Peach and Mr. L. W. Hinxman, in preparation for the issue of a new colour-printed map of the Peebles area (Sheet 24).

The death of Mr. W. Whitaker, F.R.S., on 15th January, 1925, has removed one of the Survey's veteran geologists, who, though he retired from the service in 1896, had continued to co-operate with us in many ways. Despite his having attained the ripe age of 88 years he was very active till a few months before his death, and was a frequent visitor at the Museum of Practical Geology. His reputation had been made at a very early date by his contributions to the 'Geology of the Weald' (1875), and his 'Geology of London and of Part of the Thames Valley' (1889), which had established his position as the principal authority on the Tertiary strata of the London basin. Subsequently he devoted much attention to geological bibliography and to water-supply problems. He assiduously collected records of borings in search of water from all parts of England, and in 1902 began the publication of his well-known series of memoirs on the water-supply of the counties of the south and east of England. These are a repertory of information, much of which is not otherwise obtainable, and would have been lost if he had not placed it on record. They

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form a lasting monument to his wide geological knowledge and his skill in handling evidence. Manuscripts of several memoirs, prepared by him but not yet published, are in hand, and when they have been revised, completed and brought up to date, will be published as further instalments of this useful work. The 'Water Supply of Wiltshire' has been published during the year 1925, with the assistance of Mr. F. H. Edmunds, M.A. A memoir on the 'Wells and Springs of Dorset' is in proof, revised and completed by Mr. Wilfrid Edwards, B.A. Preparations have been made for a new edition of the 'Water Supply of Sussex,' a county from which the demands for information on this subject are frequent and insistent. Mr. F. H. Edmunds has been detailed for this work. Other counties on which water-supply memoirs are being prepared are Warwickshire, Worcestershire, Derbyshire, Gloucestershire and Somersetshire.

During the early part of the summer of 1925 the Director and the Curator of the Museum of Practical Geology visited a number of Continental museums with the view of ascertaining the latest developments of museum planning and technique. This arose from the consideration of the problems of the best use of space, lighting and material available for the new Museum of Practical Geology, of which the plans are under discussion. The museums visited were Copenhagen, Oslo, Stockholm, Berlin, Dresden, Prague, Vienna, Buda-Pesth, Munich, Frankfurt-on-the-Main, Strassburg, Brussels and Paris. It was found that the conditions varied greatly. Apart from museums which are housed in buildings evidently designed for totally different ends, the museums visited could be classified almost exactly according to the period at which they were built. In other words, there has been a progressive development of museum planning, and the new museums are much better adapted to their purpose than the older ones. The best examples of modern museums, such as the Riksmuseum at Stockholm, and the Deutsches Museum at Munich, have been designed and furnished with extraordinary skill. The Natural History Museum in Brussels is in many ways remarkable for the ingenuity of its plan and the excellence of its exhibits. From a study of European museums much can be learned also as regards the most effective methods of display, labelling, illustration and storage of reference specimens. All the recent museums have abundant storage, research rooms, laboratories and libraries which make them centres of research work rather than buildings erected merely for the display of specimens.

Field-work[1].—Field-work by the Survey staff during the year 1925 has closely followed the accepted programme. The main strength of the personnel has been concentrated in the working coalfields, and the principal task has been the revision of the six-inch maps and the preparation of new maps and descriptive memoirs

[1] For details of Field-work *see* pp. 14 and 17.

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for publication. In the Midland district the Stafford (139) and Wolverhampton (153) Sheets are completely revised, and the preparation of the maps will now be put in hand. The completion of coalfield revision in North Wales has provided an opportunity to turn to the re-examination of the coalfield of South Wales. The Abergavenny Memoir being out of print, the preparation of a new edition has been placed in the hands of Dr. Robertson, who is at the same time revising the mining information on the six-inch maps of the area, which had become out of date owing to the considerable developments since the original survey. In Lancashire the Manchester Sheet (85) has absorbed the attention of the field workers. This is a district in which surface information counts for very little. There is a very long history of mining activity, and before new maps can be published a vast mass of records must be studied and digested: much of the information is very difficult to find; a good deal of it, in fact, is lost through lapse of time. A complete or reasonably complete account of the geology of such a district involves prolonged search of the records and entails much arduous labour. It is hoped, however, to finish the re-survey of the Manchester Sheet in 1926. Work will then probably be transferred to the Wigan Sheet (84). In Cumberland the publication of the Whitehaven Sheet (28) is still delayed, though certain six-inch quarter sheets have been published and others are engraving. The unit engaged on this area has, however, been doing useful work in revising the Brampton Sheet (18), which contains reserves of coals in the Limestone Measures, and also part of the small Haltwhistle Coalfield. Some of the six-inch maps of this district are now being engraved. The Yorkshire unit is now settled in its offices in York: it has completed the re-survey of the Huddersfield Sheet (77) and the six-inch maps are being prepared for the engraver. The next Sheet to be revised will be the Glossop Sheet (86) to the south, which will join up with the Manchester Sheet (85). A satisfactory beginning has thus been made with the revision of the Lancashire and Yorkshire coalfields, starting with adjacent Sheets meeting across the Pennine axis. Much work has also been done in examining shafts and borings in the very important Concealed Coalfield of Yorkshire and Nottinghamshire, on which a new edition of Dr. Gibson's memoir, revised by Mr. G. V. Wilson, is passing through the press.

In Northumberland, Mr. R. G. Carruthers and his staff have continued to work southwards and have now reached the vicinity of Morpeth. The principal areas of Lower Carboniferous coals on the east coast have been revised. About these the information was previously rather scanty. The northern part of the Cheviot Hills has been re-examined (Sheet 3). In the Northumberland district three one-inch Sheets have now been published in revised form, and two others will soon be forthcoming.

In the Scottish coalfields very satisfactory progress can be reported in the field work. The revision of the Ayrshire Coalfield

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is practically completed, though the surrounding rocks that come into the South Ayrshire Sheet (14) have still to be examined. Much new information has been collected in this area. The Muirkirk and Douglas coalfields which lie on the south margin of the Central Coalfield have been under revision and will probably be completed in 1926. In Fifeshire the rocks have been examined as far east as Dysart, but much remains to be done before the information on this complex and varied area is reasonably adequate.

The unit which works in the south-east of England under Mr. Dewey (London District) has a great number of important duties to perform. Hitherto only two geologists have been acting on this staff but it may be advisable to increase their number. The normal field programme for this group has been carried on in the Aldershot Sheet (285), but Mr. Edmunds has also contributed to water-supply memoirs and Mr. Dines has been revising the information regarding mining in the west of Cornwall. Some work has also been done by Mr. Howe and others in preparing a colour-printed edition of the Lewes Sheet (319) to accompany a new memoir by Mr. Osborne White.

Soil Mapping.—Of recent years increasing interest has been taken by British agriculturists in the mapping of soils, and Sir Thomas Middleton, on behalf of the Development Commission, has given much attention to this work. With the object of securing closer co-operation between the Geological Survey and British soil-experts a conference was held in May, 1925, at which Sir Thomas Middleton presided. The subjects under discussion were principally the relation of drift mapping to soil variations, and the types of drift maps that would be most useful to agriculturists. Various suggestions were brought forward to secure better correlation in these two fields of work. It was agreed that during the summer certain six-inch quarter sheets (each covering six square miles) should be examined conjointly by agriculturists and geologists in various parts of Britain. This has been done, and in Surrey, Staffordshire, Yorkshire, Northumberland, Cumberland, Haddingtonshire and Fifeshire field parties have been at work investigating the problem of preparing six-inch maps that would, as far as possible, satisfy the needs of practical workers on soil classification. The maps have been copied and further discussion will now take place. It is hoped that ultimately the drift maps of the Geological Survey will provide a basis for soil mapping, but the conditions vary considerably in different parts of Britain, and without extensive trials it is not possible to say definitely what type of drift map will best meet the demand.

Publications[1].—As may be seen from the list of publications appended the number of new maps which have been in the press during 1925 was exceptionally large. Nine English one-inch maps have been issued. These include the first revised maps of Cumber-

[1] For details *see* pp. 15, 16, 18, 19.

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land and Northumberland and the completion of the revised one-inch maps of London and district as far east as Romford. Among the maps which are being engraved is the first revised Lancashire Sheet (Rochdale, 76). In Scotland four one-inch Sheets have been published. Three of these represent Highland districts. In addition, two Highland Sheets are in the press (Tiree, 42 and 50, and Coll, 51), and when these are issued nearly all Highland work will have been published so far as surveyed. The other Scottish Sheet issued during 1925 (Wigtown, 4) marks the continuation of the policy of making new colour-printed maps showing the full results of the revision of the Silurian rocks of the south of Scotland by Drs. Peach and Horne.

In the south-east of England the demand for cheap colour-printed maps has justified the preparation of several Sheets. Marlborough (266) has been published; Lewes (319) is engraving; Hastings (320) is in hand; and Ramsgate (274) and Dover (290) will follow. The old survey in these districts was often not seriously defective and has been kept up to date in many respects as occasion offered. The new issues are based on the Old Series with such amendment as seems necessary but without complete re-survey.

Another feature of the year's publications which calls for notice is the resumption of the publication of vertical sections. Two Sheets of the Concealed Coalfield of Yorkshire and Nottinghamshire, showing in detail, colour-printed, all the principal sinkings and borings in this most important district, were issued during the year. A similar Sheet was prepared for North Ayrshire. To mining engineers this kind of information is especially valuable, as it presents in compact form perfectly reliable facts regarding the sequence in the principal coalfields, and most usefully supplements the information contained in maps and memoirs.

Of the memoirs published during the year several were descriptions of the areas embraced in new colour-printed one-inch maps; of these, Birmingham, North London and Romford are densely populated districts of which the geology had not been officially revised for a long period. Three volumes of the Special Mineral Reports were issued, of which two were new, and the third was a revised edition of the 'Hæmatites of West Cumberland, Lancashire and the Lake District.' The demand for these Special Reports continues, and several of the volumes will probably be sold out before long; the preparation of new editions necessitates a complete revision of the evidence, and involves much detailed work such as examination of mines and plans, but the value of this series of memoirs depends entirely on their accuracy. Towards the close of the year arrangements were made for the revision of the memoir on the Iron Ores of the Forest of Dean and South Wales in preparation for the issue of a second edition.

Mr. H. J. Osborne White has continued to assist the Survey by the preparation of memoirs on districts in the south of England. His memoir on Marlborough has been issued and the memoir on

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Lewes was completed in manuscript and prepared for the press. He has also taken in hand a description of the Hastings and Dungeness Sheets (320 and 321), the publication of which will follow. Professor P. G. H. Boswell, of Liverpool University, has written a memoir on the Ipswich Sheet (207), which will be published along with a new colour-printed edition of the map; and he has also undertaken a description of the Woodbridge and Felixstowe Sheets (208 and 225).

The first volume of Dr. Kidston's 'Fossil Plants of the Carboniferous Rocks of Great Britain' has been completed by the issue of the sixth part, including an index to the whole volume. Most valuable assistance has been given in this work by Mr. Chatwin, who has seen all the parts through the press and has prepared the index. No further parts can be issued for some time, though it is hoped ultimately to complete the monograph by the publication of a second volume. Meanwhile, the Kidston collection has been transferred to the Museum of Practical Geology, where it is preserved in the original cabinets as it was arranged by Dr. Kidston. A full catalogue, with references to literature, details of figured specimens, types, etc., is in preparation and may be published soon. Two table cases on the entrance floor of the Museum have been filled with characteristic plant specimens from this collection, illustrated with plates from the monograph. Consequently, the Kidston collection is now in such a condition that research workers who wish to examine the specimens may do so freely.

The memoirs issued during the year 1925 by the Scottish staff have been both numerous and important. Two of these form the completion of the description of Mull and the adjacent country, and with the publication during the year of one-inch Sheet 43 (Iona) bring our work in that remarkable volcanic country to a satisfactory termination.[1] A new and enlarged edition of the important Glasgow Memoir has been edited by Mr. Murray Macgregor, and includes a considerable amount of detailed information that has been added to our store during the last fifteen years. The memoir on the Oil Shales of the Lothians has been partly revised and new chapters on the chemistry of the oil-shales and on the history of the oil-shale industry have been written by Mr. E. M. Bailey and Mr. H. R. J. Conacher, who have had a long and intimate connexion with this industry in Scotland, and are well known authorities on the subjects with which they deal. Mr. Murray Macgregor has also prepared a new edition of the Coatbridge and Airdrie Memoir (Economic Geology of Central Coalfield, Area V), which at the close of the year was almost ready for issue. Attention may also be directed to the publication of the first two memoirs on the Economic Geology of the Ayrshire Coalfields. It is intended to complete the minute description of this area by

[1] Sheet 44 (Mull) and the Memoir on the 'Tertiary and Post-Tertiary Geology of Mull, Loch Aline, and Oban' were issued in 1923 and 1924 respectively.

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the publication of further memoirs on the remaining portions of the coalfield, of which one is in preparation. The memoir on the 'Geology of the Country around Golspie, Sutherlandshire' has a special interest, as it contains a general account of the richly fossiliferous Secondary rocks of the Brora, Shandwick and Ethie districts (all on the north side of the Moray Firth) which have attracted much attention from geologists and palæontologists. In this memoir the services of Mr. S. S. Buckman, a leading British authority on the Ammonites, must be acknowledged.

Owing to the exhaustion of the first edition of the Geological Survey Memoir on North Arran (published 1903) it became necessary to make arrangements for a new edition, as Arran is one of the most fascinating districts of Scotland from the standpoint of the geologist. Since the regular Survey staff was fully employed in other important districts, Dr. G. W. Tyrrell, of Glasgow University, was requested to undertake the work. It is intended to issue a new memoir with a complete description of the geology of the island. Dr. Tyrrell has consented to prepare the manuscript and has spent some time in Arran during the summer of 1925 visiting the exposures and drafting his account of the geology. The original field maps and specimens collected by the Survey have been placed at his disposal, and he is to make use also of the large collections in Glasgow University made by himself and other geologists. At the close of the year the manuscript was in preparation, but was not yet ready for the printer. It is not at present intended to revise the colour-printed one-inch map of Arran issued by the Survey in 1910.

General Work[1].—On the Petrographical and Chemical departments increasing demands have been made, owing to the large area now being revised. Dr. Thomas has devoted his time mainly to the difficult petrology of the Tertiary rocks of the west of Scotland, and Dr. Read, Mr. Phemister, Mr. A. G. MacGregor and Mr. Bailey have investigated the rocks collected in, or adjacent to, the districts which they have personally mapped.

The activities of the palæontological staff during the year have been very largely directed to supporting the work of the field surveyors in the districts now under revision by supplying accurate palæontological data regarding the fossils obtained in the course of their work. Dr. Kitchin's work has been in large measure editorial and curatorial, but Mr. Pringle has visited several borings and spent a good deal of time in the field in the Oxford district, and Mr. Chatwin, in addition to editing the last two parts of Dr. Kidston's monograph, has kept closely in touch with the work of the field staff in the south and east of England and has examined many sections exposed by the cuttings of the new roads now being constructed near London.

A great deal of work in this Department is entailed by the demands of geologists wishing to study the fossils in the Geological

[1] For details *see* pp. 19–22.

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Survey collections, and, as will be seen from the list of specimens figured during the year (p. 132), they are freely placed at the disposal of investigators, with the result that many of them are selected as types of new species and the importance of our collections is thereby greatly enhanced.

Museum of Practical Geology.[1]—The Museum has been closed for more than half the year as H.M. Office of Works had not completed the erection of temporary supports. As soon as this was done, and the Museum reported safe for public use, the Curator began to have the exhibits cleaned and rearranged. A new system of electric lighting was introduced and it was found possible to admit the public, though much of the material exhibited cannot be seen under satisfactory conditions. The Library has remained open to the public since the door in Piccadilly was made about two years ago, and the maps and literature have been available to students, engineers and geologists, who continue to consult the Library of the Geological Survey in increasing numbers.

I.—SURVEY WORK

(I)—ENGLAND AND WALES

Field-work

London and South Eastern District.—Field-work was continued in Sheet 285 (Aldershot) by Mr. Dines and Mr. Edmunds under Mr. Dewey, District Geologist. A small amount of revision was also undertaken in Sheet 319 (Lewes).

Mr. Pringle, too, collected much data in the Oxford District; while Mr. Dines also revised the mining information relating to the west of Cornwall.

Midland District.—Field-work was carried on by Mr. Pocock, Mr. Whitehead and Dr. Robertson in Sheets 153 (Wolverhampton), 152 (Shrewsbury) and 139 (Stafford) under the superintendence of Mr. Cantrill, District Geologist. Work was completed in Sheets 153 and 139. Dr. Robertson also completed his examination of the rocks exposed in the new Colwall Tunnel, and collected much mining information in Sheet 232 (Abergavenny).

Yorkshire District.—Work was completed in Sheet 77 (Huddersfield) and commenced in Sheet 86 (Glossop) by Mr. Wilson, Mr. Wray, Mr. Stephens and Mr. Edwards, Mr. Bromehead acting as District Geologist. Mr. Wilson has also visited mines and borings in the Concealed Coalfield.

Lancashire District.—Dr. Sherlock, Mr. Lloyd, Mr. Tonks, Mr. Jones, with Mr. Wright, District Geologist, continued work in Sheet 85 (Manchester).

Cumberland District.—Work has been continued in Sheet 28 (Whitehaven), Sheet 22 (Maryport), and Sheet 18 (Brampton) by Mr. Dixon, Mr. Eastwood, Mr. Trotter and Mr. Hollingworth under the supervision of Dr. Bernard Smith, District Geologist.

Northumberland and Durham District.—Mr. R. G. Carruthers, District Geologist, and Mr. Burnett, Mr. Maden, Mr. Fowler and Mr. W. Anderson continued work in Sheets 3 (Ford), 6 (Alnwick), 9 (Rothbury), 10 (Woodhorn),

[1] For details *see* p. 22.

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14 (Morpeth), and 20 (Newcastle-on-Tyne). Work in Sheets 3 and 6 was completed.

Indoor Work

The manuscripts of the following memoirs were being written or edited for publication :—

South Staffordshire Coalfield south of the Bentley Fault.
Water Supply of Gloucestershire ; of Derbyshire ; of Worcestershire ; of Somersetshire ; and of Warwickshire.
Explanations of Sheets 4 (Belford), 76 (Rochdale), 121 (Wrexham), 137 (Oswestry), 139 (Stafford), 207 (Ipswich), 208 and 225 (Woodbridge and Felixstowe), 232 (Abergavenny) *Second Edition*, 319 (Lewes), 320 and 321 (Hastings and Dungeness).

The following maps and memoirs were published or passing through the press in 1925 :—

I.—MAPS

Published.

1 inch to 1 mile :—

Sheet 1 (Norham, solid edition), Sheet 2 (Berwick-on-Tweed, solid edition), Sheet 4 (Holy Island, solid edition), Sheet 11 (Longtown, drift edition), Sheet 16 (Silloth, drift edition), Sheet 17 (Carlisle, drift edition), Sheet 256 (North London, drift edition), Sheet 257 (Romford, drift edition), Sheet 266 (Marlborough, drift edition).

6 inches to 1 mile :—

Cumberland, 53 S.W. ; 61 N.W., S.W.
Denbighshire, 28 N.W. (Flint 19 N.W.), N.E., S.W., S.E. ; 29 S.W. ; 35 N.W., N.E., S.W., S.E. (Flint 21 S.E.) ; 36 S.W. (Flint 22 S.W.) ; 40 N.W., N.E. (Flint 24 N.E.), S.W., S.E.
Lancashire, 63 S.W., S.E. ; 64 S.W., S.E. ; 65 N.W., S.W. ; 71 N.W., N.E., S.W., S.E. ; 72 N.W., N.E., S.W., S.E. ; 73 N.W., S.W., 73 (S.E. & 81 N.E.) ; 79 N.W., N.E., S.W., S.E. ; 80 N.W., N.E., S.W., S.E. ; 81 N.W., S.W., S.E.
Northumberland, 6 N.E., S.E. ; 7 S.W. ; 16 N.W., S.W. ; 17 (S.W. & S.E.) ; 21 N.E. ; 22 N.E. ; 27 N.W., N.E., S.W., S.E., ; 32 N.W., N.E.

Vertical Sections :—

Sheet 91 (Sections of Borings and Shafts in the Northern Part of the Concealed Coalfield of Yorkshire and Nottinghamshire).
Sheet 92 (Sections of Borings and Shafts in the Concealed Coalfield of Nottinghamshire.)

In the press, engraving or colour-printing.

1 inch to 1 mile :—

Sheet 1 (Norham, drift edition), Sheet 2 (Berwick-on-Tweed, drift edition), Sheet 4 (Holy Island, drift edition), Sheet 76 (Rochdale, solid edition), Sheet 121 (Wrexham), Sheet 154 (Lichfield, solid edition), Sheet 169 (Coventry, solid edition), Sheet 319 (Lewes).

6 inches to 1 mile :—

Cumberland, 18 S.W., S.E. ; 61 N.E. ; 67 N.E. (New Ed.) ; 72 N.W.
Lancashire, 79 S.W., S.E.
Northumberland, 16 N.E. ; 26 N.W., N.E., S.E. ; 45 N.E. ; 53 S.E. ; 54 N.W., S.W.

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Copies of the following six-inch sheets, which are not to be published, were deposited in the Library for public reference :—

Cheshire, 30 S.E. ; 31 S.W. ; 38 N.W.

Cumberland, 68 S.W.

Denbighshire, 19 N.E., S.E. ; 20 N.W. (Flint 16 N.W.), S.W. (Flint 16 S.W.) ; 22 N.W. (Flint 17a N.W.).

Essex, 57 N.W., N.E., S.W., S.E. ; 58 N.W., N.E., S.W., S.E. ; 59 N.W., N.E., S.W., S.E. ; 60 N.W., N.E., S.W., S.E. ; 65 N.W., N.E., S.W., S.E. ; 66 N.W., N.E. ; 67 N.W., N.E., S.W., S.E. ; 68 N.W., N.E., S.W., S.E. ; 76 N.W., N.E., S.W., S.E.

Flintshire, 8 N.W. (Denbigh 9 N.W.), N.E. (Denbigh 9 N.E.), S.W. (Denbigh 9 S.W.), S.E. (Denbigh 9 S.E.) ; 9 S.W. ; 10 N.E. ; 11 S.W. ; 12 N.E. (Denbigh 14 N.E.), S.E. (Denbigh 14 S.E.) ; 13 N.W., S.W. (Denbigh 15 S.W.) ; 14 S.E. ; 15 N.W., S.W. ; 17 N.E. (Denbigh 21 N.E.).

Hertfordshire, 44 N.E. (Middlesex 5 N.E.), S.E. (Middlesex 5 S.E.).

London, H (part) ; J (part) ; L (part).

Middlesex, 6 N.W. (Herts. 45 N.W.), N.E. (Herts. 45 N.E.), S.W. (Herts. 45 S.W.), S.E. (Herts. 45 S.E.) ; 7 N.W., N.E. (Essex New Series N. 68 N.E.), S.W. (Herts. 46 S.W.) ; 10 N.E., S.E., 11 (London F) ; 12 (London G).

Shropshire, 20 N.W., N.E., S.W., S.E. ; 21 N.W., N.E., S.W., S.E. ; 22 N.W., N.E., S.W., S.E. ; 23 N.W., S.W. ; 27 N.W., N.E., S.W., S.E. ; 28 N.W., N.E., S.W., S.E. ; 29 N.W., N.E., S.W., S.E. ; 30 N.W., S.W.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1924. 154 pp. ; 11 text-figures. 1925. Price 2s. 6d. net.

Special Reports on the Mineral Resources of Great Britain :—

Vol. VIII.—Iron Ores : Hæmatites of West Cumberland, Lancashire and the Lake District. *Second Edition.* By B. Smith, M.A., Sc.D. 236 pp. ; 5 plates ; 31 text-figures. 1924. Price 5s. net.

Vol. XXIX.—Iron Ores : Bedded Ores of England and Wales. Petrography and Chemistry. By A. F. Hallimond, M.A., with an Appendix by F. R. Ennos, B.A., B.Sc., A.I.C., and R. Sutcliffe, M.A., A.I.C. 139 pp. ; 8 plates ; 3 text-figures. 1925. Price 3s. net.

Vol. XXX.—Copper Ores of the Midlands, Wales, the Lake District and the Isle of Man. By Henry Dewey and T. Eastwood, A.R.C.Sc., with contributions by Bernard Smith, M.A., Sc.D., and R. G. Carruthers. 87 pp. ; 6 plates. 1925. Price 2s. net.

Monograph on the Fossil Plants of the Carboniferous Rocks of Great Britain. (Palæontology : Vol. II.) By Robert Kidston, LL.D., D.Sc., F.R.S.L. & E., F.G.S.

Part 5, 146 pp. ; 31 collotype-plates ; 29 text-figures. 4to. 1924. Price 20s. net.

Part 6 (including Title-page, Contents, Preface and Index to Palæontology : Vol. II), 159 pp. ; 31 collotype-plates ; 39 text-figures. 4to. 1925. Price 22s. 6d. net.

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The Water Supply of Wiltshire from underground sources. By W. Whitaker, B.A., F.R.S., and F. H. Edmunds, M.A. 133 pp.; 1 plate; 6 text-figures. 1925. Price 4s. 6d. net.

List of Memoirs, Maps, Sections, &c., published by the Geological Survey of Great Britain and the Museum of Practical Geology to 30th June, 1925. 1925. Price 1s. net.

The Geology of the Country around Stoke-on-Trent. (Explanation of one-inch Sheet 123: England.) *Third Edition. Revised.* By Walcot Gibson, D.Sc., F.R.S., with contributions by C. B. Wedd, B.A. and A. Scott, M.A., D.Sc. 112 pp.; 2 plates; 15 text-figures. 1925. Price 2s. 6d. net.

The Geology of the Country around Wem. (Explanation of one-inch Sheet 138: England.) By R. W. Pocock, B.Sc., and D. A. Wray, M.Sc., with contributions by T. C. Cantrill, B.Sc. 125 pp.; 5 plates; 2 text-figures. 1925. Price 3s. net.

The Geology of the Country around Birmingham. (Explanation of one-inch Sheet 168: England.) By T. Eastwood, A.R.C.Sc., Talbot H. Whitehead, M.Sc., A.R.C.Sc., and T. Robertson, B.Sc., A.Inst.M.M., with contributions by T. C. Cantrill, B.Sc. 152 pp.; 7 plates; 1 text-figure. 1925. Price 4s. net.

The Geology of North London. (Explanation of one-inch Sheet 256: England.) By C. E. N. Bromehead, B.A., with contributions by H. G. Dines, A.R.S.M., A.M.Inst.C.E., and J. Pringle. 63 pp.; 1 plate; 1 text-figure. 1925. Price 1s. 6d. net.

The Geology of the Country around Romford. (Explanation of one-inch Sheet 257: England.) By H. G. Dines, A.R.S.M., A.M.Inst.C.E. and F. H. Edmunds, M.A. 53 pp.; 2 plates; 3 text-figures. 1925. Price 1s. 6d. net.

The Geology of the Country around Marlborough. (Explanation of one-inch Sheet 266: England.) By H. J. Osborne White. 112 pp.; 3 plates; 11 text-figures. 1925. Price 2s. 6d. net.

In the press.

The Geology of the Country around Oxford. (Explanation of Oxford Special Sheet.) *Second Edition.*

The Concealed Coalfield of Yorkshire and Nottinghamshire. *Second Edition.*

Wells and Springs of Dorset.

The Geology of Berwick-on-Tweed, Norham and Scremerston. (Explanation of one-inch Sheets 1 and 2: England.)

The Geology of the Carlisle, Longtown and Silloth District. (Explanation of one-inch Sheets 11, 16 and 17: England.)

(2)—SCOTLAND

Field-work

Ayrshire.—Under Mr. E. B. Bailey, District Geologist, field-work was continued in one-inch Sheet 14 (Ayr) by Messrs. Eyles, Simpson and A. G. MacGregor. A little revision work was also done on the east margin of one-inch Sheet 22 (Kilmarnock).

Lanarkshire, Ayrshire and Peeblesshire.—Messrs. Anderson, Ross and Phemister, under the supervision of Mr. J. E. Richey, District Geologist, have completed the revision of one-inch Sheet 23 (Lanark). Messrs. Richey, Read and Phemister re-examined the greater part of the Old Red Sandstone and Carboniferous areas in one-inch Sheet 24 (Peebles) and Mr. Anderson continued field-work in one-inch Sheet 15 (Sanquhar).

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Fifeshire.—Under Mr. C. H. Dinham, District Geologist, revision work has been continued in one-inch Sheet 40 (Dunfermline) by Messrs. Haldane, Allan and Knox.

Indoor Work

The manuscripts of the following memoirs were being written or prepared for publication :—

The Economic Geology of the Clackmannan and North Stirlingshire Coalfield.

The Economic Geology of the Central Coalfield of Scotland, Area I.—Kirkintilloch and Kilsyth.

The Geology of Tiree. (Explanation of one-inch Sheets 42 and 50.)

The Geology of Coll, Ardnamurchan and Western Mull. (Explanation of one-inch Sheet 51.)

The following maps, memoirs and sections were published or passing through the press in 1925 :—

I.—MAPS

Published.

1 inch to 1 mile :—

Sheet 103 (Golspie), Sheet 102 (Strath Oykell), Sheet 43 (Iona), Sheet 4 (Wigtown).

6 inches to 1 mile :—

Ayrshire, 9 N.W. ; 12 N.E., S.E. ; 13 N.W., S.W., S.E. ; 18 N.E., S.W. ; 19 S.W. ; 24 N.W.

Lanarkshire, 19 N.E.

Renfrewshire, 14 N.E.

Vertical Sections (scale 1 inch to 40 feet, colour-printed) :—

Sheet 8, Ayrshire Coalfields (Areas I and II), Kilmarnock, Stevenston and Kilbirnie Districts.

In the press, engraving or colour-printing.

½ inch to 1 mile :—

Sheet 9 (Banffshire, Eastern Elginshire, Northern and Central Aberdeenshire, etc.).

1 inch to 1 mile :—

Sheet 51 (Coll and Ardnamurchan), Sheets 42 and 50 (Tiree), Sheet 7 (Ballantrae).

6 inches to 1 mile :—

Ayrshire, 21 S.E. (and 22 S.W.) ; 22 S.E. ; 23 S.W., S.E. ; 24 S.W. ; 27 N.W., N.E., S.W., S.E. ; 28 N.W., N.E., S.W., S.E. ; 29 N.W., S.W. ; 33 N.W., N.E. ; 34 N.W., N.E., S.E. ; 35 N.W., N.E., S.W.

Renfrewshire, 11 S.W.

Perthshire and Clackmannanshire, 133 S.W., S.E. ; 134 S.W., S.E. ; 139 N.E.

Fifeshire, 32 N.E. ; 37 N.W.

Copies of the following six-inch sheets, which are not to be published, were deposited in the Office for public reference. These are whole sheets, each consisting of four quarter-sheets, except where otherwise stated :—

Aberdeenshire, 17.

Argyllshire, 94 ; 106 ; 116a and b N.W., N.E., S.E. ; 117 ; 118 N.W., N.E., S.W.

Ayrshire, 57 ; 58 ; 59 N.W. ; 63 ; 64 ; 67 ; 68 N.W., S.W. ; 71 ; 72 N.W., S.W.

Banffshire, 3 ; 4.

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Lanarkshire, 32 N.W.; 33 N.W., S.W., S.E.; 38 S.E.; 39 N.E., S.W.

Sutherlandshire, 90; 109; 110; 111 N.W., N.E., S.E.; 112; 113 N.W., S.W.

II.—MEMOIRS

Published.

Summary of Progress of the Geological Survey of Great Britain for 1924. *See* p. 16.

The Economic Geology of the Ayrshire Coalfields, Area I.—Kilbirnie, Dalry and Kilmaurs. By J. E. Richey, M.C., B.A.; G. V. Wilson, B.Sc., and E. M. Anderson, M.A., B.Sc.; with contributions by C. H. Dinham, B.A. 91 pp.; 2 plates; 8 text-figures. 1925. Price 2s. 6d. net.

The Economic Geology of the Ayrshire Coalfields, Area II.—Kilmarnock Basin, including Stevenston, Kilwinning and Irvine. By E. M. Anderson, M.A., B.Sc., with contributions by G. V. Wilson, B.Sc. 107 pp.; 2 plates; 10 text-figures. 1925. Price 3s. net.

The Geology of the Glasgow District. *Revised Edition.* By M. Macgregor, M.A., B.Sc.; C. H. Dinham, B.A.; E. B. Bailey, M.C., B.A., and E. M. Anderson, M.A., B.Sc. 299 pp.; 1 folding plate; 30 text-figures. 1925. Price 7s. 6d. net.

The Pre-Tertiary Geology of Mull, Loch Aline, and Oban. (Explanation of parts of one-inch Sheets 35, 43, 44, 45 and 52.) By G. W. Lee, D.Sc., and E. B. Bailey, M.C., B.A.; with contributions by S. S. Buckman and H. H. Thomas, M.A., Sc.D. 140 pp.; 2 plates; 13 text-figures. 1925. Price 4s. 6d. net.

The Geology of Staffa, Iona and Western Mull. (Explanation of one-inch Sheet 43.) By E. B. Bailey, M.C., B.A.; and E. M. Anderson, M.A., B.Sc.; with contributions by G. A. Burnett, B.Sc.; J. E. Richey, M.C., B.A.; G. W. Lee, D.Sc.; W. B. Wright, B.A.; G. V. Wilson, B.Sc.; with petrological notes by H. H. Thomas, M.A., Sc.D. 107 pp.; 1 plate; 11 text-figures. 1925. Price 3s. net.

The Geology of the Country around Golspie, Sutherlandshire. (Explanation of one-inch Sheet 103.) By H. H. Read, D.Sc., A.R.C.Sc.; G. Ross, B.Sc., and J. Phemister, M.A., B.Sc., including a description of the Mesozoic Rocks of East Sutherland and Ross (Helmsdale, Brora, Golspie, Shandwick, and Ethie). By G. W. Lee, D.Sc. 143 pp.; 2 plates; 7 text-figures. 1925. Price 3s. 6d. net.

In the press.

The Economic Geology of the Central Coalfield of Scotland, Area V—Glasgow East, Coatbridge and Airdrie. *Second Edition.*

The Geology of Strath Oykell and Lower Loch Shin. (Explanation of one-inch Sheet 102.)

The Oil Shales of the Lothians. *Third Edition.*

II.—GENERAL WORK

A.—PETROGRAPHICAL DEPARTMENT

The work on the petrography of the Tertiary igneous rocks of Ardnamurchan has been continued by the Petrographer, in collaboration with Mr. Richey, for the forthcoming memoir descriptive of Sheet 51 and part of Sheet 52, Scotland.

Dr. Thomas visited Ardnamurchan with Mr. Richey to investigate certain points that had arisen during the microscopical study of the rocks concerned. As a preliminary to petrological work on the Carboniferous rocks of Fifeshire

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a visit was made to that district, and he assisted Mr. Pocock in the field to establish the extrusive nature of a considerable mass of basalt associated with Lower Carboniferous rocks in the neighbourhood of Wellington, Salop.

He has continued his investigations, at the request of the Health Advisory Committee of the Mines Department, into the nature of dusts, etc., collected from colliery and other workings.

Dr. Read and Mr. Phemister have completed their detailed petrographical work on the igneous and metamorphic rocks of Strath Oykell and Golspie. Dr. Read has made a revision of the dyke-rocks of a large part of southern Scotland, and good progress has been made by Messrs. A. G. MacGregor and Phemister with the petrography of the Ayrshire lavas and minor intrusions. Mr. Bailey has undertaken the petrography of the rocks of Coll and Tiree, and Dr. Tyrrell, of Glasgow University, has been entrusted with the revision of the petrography of Arran for a new edition of the memoir on that island.

The number of rock-specimens sliced and registered in the collections is as follows :—

English	13,069
Scottish	24,671
Irish	447
Foreign	2,551
Total	40,738

This represents an increase of 1,097 in the registered sliced rocks during the year. Of the corresponding sections 643 were made in the English Office and 454 in the Scottish Office.

The collections have, as usual, been freely referred to by officers of the Survey and others.

In addition, 1,733 sections and 609 rock-specimens have been despatched on loan to Survey officers and 587 sections and 41 rock-specimens to private individuals.

B.—PALÆONTOLOGICAL DEPARTMENT

England and Wales.—The fossils added to the collections during the year numbered 5,380 specimens. The presentations included a series of Ordovician fossils from Carnarvonshire, the gift of Dr. C. A. Matley. Fossil collecting has been carried out by Messrs. A. Templeman and S. W. Hester, principally in Surrey, Oxfordshire, Shropshire and Cumberland. The study of the specimens obtained is in progress.

Mr. Pringle completed his examination of the area embraced by the Special Oxford Sheet and the work of writing the new edition of the memoir relating to it. He visited the sites of borings in Oxfordshire at Alvescote, near Burford, and at Cumnor, and in company with Mr. G. V. Wilson he saw the cores of the deep boring at Doddington, near Lincoln. Mr. Pringle examined fossil-localities in the neighbourhood of Wellington, Salop, and in the district of Gilsland and Castle Carrock, Cumberland, where he gave assistance to the field-officers engaged in the survey of that area. He also accompanied Dr. T. Robertson in visits to the new tunnel-excavations at Colwall, near Malvern.

Dr. Kitchin examined several thousand specimens of fossils, including a large part of the collections obtained from the Millstone Grit Series of Lancashire. He spent much time in editorial work and in preparing for press the manuscripts of palæontological monographs.

Mr. Chatwin visited fossil-localities near Guildford and examined fossils obtained from that area. He also visited borings at Virginia Water and Wokingham; sections exposed in road-widening between Aston Hill and

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Ietsworth (Oxfordshire); and sections in the Chalk in and around Norwich. Mr. Chatwin edited and passed through the press Parts 5 and 6 of the late Dr. Kidston's monograph, preparing also the index and other pages for the completion of Volume II. of the Palæontological Memoirs. Much time was spent by him in work on the Kidston Collection of fossil plants. The collection has been unpacked and arranged in the original cabinets, which have now been provided with covers within each drawer for the protection of the specimens from dust. Miscellaneous materials and manuscripts received with the collection have been sorted and arranged. A case containing some choice figured specimens from the Kidston Collection has been arranged in the Museum by Mr. Hester. Mr. Morgan has spent most of his time during the year in the preparation of a comprehensive catalogue of the whole collection, in which there will be cross-references to the collection of about 4,000 photographic negatives.

Other items of work done in the Department include the revision of the Carboniferous palæontology for the new editions of the memoir on the Concealed Coalfield of Yorkshire and Nottinghamshire, the Stoke-on-Trent memoir and the Abergavenny memoir; also the provision of fossil-lists for the Wrexham and Oswestry memoirs. Numerous enquiries have, as usual, been dealt with, and assistance has been given to advanced students and others seeking information or engaged in researches.

Since the removal of the protective coverings from the exhibition-cases and the opening of the Museum, work has been resumed on the palæontological galleries. The systematic cleaning of the specimens and tablets is now in progress. Nearly 2,000 specimens of fossils have been sent out on loan from the department for the purpose of study.

Scotland.—Fossils to the number of 2,587 were collected by Messrs. Tait, Eckford and Strachan, Carboniferous in age with few exceptions. A considerable proportion of these was obtained from borings, the rest being from excavations and natural exposures.

A large number of Mesozoic fossils added to the cases allotted to the Survey in the Royal Scottish Museum brings the Jurassic part of the exhibits near completion.

Apart from the naming of fossils collected during the year, Dr. G. W. Lee spent some time on the revision of the Carboniferous section of the Arran memoir, and this work involved the re-examination of about 1,500 specimens.

C.—CHEMICAL DEPARTMENT

At the close of 1925 the numbers of rock-specimens registered in the Laboratory Records as having been or as being analysed are as follows:—

English	323
Scottish	435
Irish	2
Welsh	55
Others	45
Total	860

The Chemical Department has completed thirty-one of these analyses in the past year, and fourteen others are still in progress. Sixteen qualitative examinations have been undertaken for Survey officers, and a considerable number of inquiries were dealt with, including some from the Fuel Research Board relative to routine methods of analysis used in this department.

A limited amount of research work in connexion with certain analyses was necessary, but, owing to the general demand for analytical work, time spent on research was severely restricted and only sufficient was undertaken to elucidate the analyses concerned.

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D.—PHOTOGRAPHIC WORK

England and Wales.—Mr. J. Rhodes has taken 306 photographs of geological subjects to form part of the registered series of English photographs.

The number of registered negatives is now as follows :—

English photographs	3,247
Photomicrographs	1,610
Miscellaneous	1,434

Amongst the miscellaneous photographs taken mention may be made of 134 negatives and corresponding prints of fossils prepared in connexion with a palæontological memoir on the Carboniferous *Producti*.

Mr. Rhodes has made 1,114 prints, mostly of geological views, for the albums in London and Edinburgh. He has also carried out the corresponding mounting.

He prepared during the year 369 lantern-slides, which have been added to the nucleus of a reference collection.

Scotland.—Mr. W. Manson has taken 110 photographs of geological subjects in Scotland during 1925.

III.—MUSEUM OF PRACTICAL GEOLOGY

The completion of the temporary structures to support the roof of the Museum made possible the resumption of museum work. The stores in the basement were reorganised and study and reserve material has, as far as possible, been made available. Before the reopening of the Museum to the public it was found necessary to reduce the exhibited collections, and upwards of 20 cases of exhibits were dismantled, the specimens transferred to store and the cases removed to accommodation provided by H.M. Office of Works. It was necessary also to find space on the ground floor for the valuable Kidston Collection of Carboniferous plants. The unsightly wooden scaffolds have as far as possible been screened off and hung round with exhibits of maps and photographs, whilst a new system of electric lighting has been installed throughout the galleries.

The Museum was reopened to the public on August 4th, and since that date the attendance has totalled 5,443, the daily number of visitors showing a decided upward tendency as it became known that the collections were once more available.

In the Mineral Department the cataloguing and registration of unregistered material is now approaching completion. The cleaning of the horseshoe and wall cases has been completed. New exhibits have been arranged to illustrate the Special Reports on iron ores, and recently acquired gemstones are temporarily arranged in a special case. Specimens numbering 241 have been registered and card-indexed, whilst 1,286 specimens in the Ludlam Collection have been entered in the special inventory. One hundred and fifteen rock sections were prepared and transferred to the Survey collection.

The additions to the Library during the year comprise 354 volumes of independent works, 3,135 volumes and parts of serials, 405 maps and 224 pamphlets. In the same period 349 volumes were bound, 481 maps were mounted and 362 photographs and lantern-slides were supplied to the public.

The number of special enquirers who signed the enquiry book was 3,238.

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LIST OF DONATIONS DURING THE YEAR 1925

ANDREW, G., ESQ., B.Sc., F.G.S.—Two specimens of brachiopods from the Lower Llandovery of Garth, Brecknockshire.

ASHCROFT, F. N., ESQ., M.A., F.C.S., F.G.S.—Specimen of wulfenite from Mezica, Yugoslavia.

ASHMORE, C. P., ESQ.—Specimen of concentrates from diamond deposits of Atiankumbra, Gold Coast; also sample of diamonds.

BOGGILD, PROFESSOR O. B.—Thirty-one specimens of minerals and rocks from Greenland.

CAMPBELL, DR. R.—Three specimens of tholeiite from Dalmahoy and Kaimes Hills, containing chlorophaeite.

COOK, MISS L. A.—One specimen of *Pecten* (*Aequipecten*) *pexatus* Woods, from the Chalk of Kent.

COOK & SONS, LTD., MESSRS. T.—A *Nautilus* from the London Clay, 25 feet below surface of excavations (on Devonshire House site) in Berkeley Street, W. 1.

COOK, W. H., ESQ.—Two specimens of *Schloenbachia sp.* from the Chalk Marl at new quarry near Holborough.

COTSWORTH, T. G., ESQ.—A specimen of plant from the Middle Coal Measures of Treharris, Glamorganshire.

EDGE, S. R. H., ESQ.—Calcite from drum of pulp machine.

EDWARDS, H. S. W., ESQ.—A specimen of Roman slag.

EVANS, J. LEE, ESQ.—Two specimens of gold ore from Prince of Wales Mine, Dolgelly, Merionethshire.

HENDRIKS, MISS E. M. L.—Nine rocks from western side of Nare Head, Cornwall.

HEWITT, H. D., ESQ., F.I.C.—A series of Chalk fossils from various localities in the district around Thetford, Norfolk.

HITCHIN, C. S., ESQ.—One specimen of *Micraster coranguinum* (Leske) from the Chalk of Kent.

HORNE, DR. J., F.R.S.—156 sections from one-inch Sheets 76, 86, 96, Scotland.

ISLIP IRON CO., LTD., MESSRS. THE, per N. W. KIDNER, ESQ.—Two vertebrae of *Steneosaurus sp.* (a marine crocodile) from the Great Oolite of Thrapston, Northamptonshire.

JACK, G. H., ESQ., M. INST. C.E., F.R.I.B.A., F.G.S.—A fragment of Eurypterid from the Upper Old Red Sandstone of Longtown, south-west of Hereford.

JACKSON, J. W., ESQ., M.Sc., F.G.S.—Six specimens of brachiopods from the Wenlock Shale of Shropshire.

JONES, PROFESSOR O. T., D.Sc., F.R.S.—Six specimens of Ordovician and Silurian brachiopods from various localities in Wales.

MATLEY, C. A., ESQ., D.Sc., F.G.S.—A large series of Ordovician fossils from the South-West Lleyn district, Carnarvonshire.

MILNER, DR. H. B.—One micro-slide of garnet-hornfels from Longships, Land's End, Cornwall.

NEW ZEALAND SECTION, WEMBLEY EXHIBITION, THE COMMISSIONER.—A cube of Coromandel (New Zealand) granite.

PARKINSON, DR. J.—31 sections from the Prescelly Mountains, Pembrokeshire.

RICHARDSON, L., ESQ., F.R.S.E., F.G.S.—A series of Jurassic fossils from various localities in the West of England, and a series of Mollusca from the Great Oolite of Gloucestershire.

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SMITH, S., ESQ., M.A., D.Sc., F.G.S.—A specimen of *Aulina furcata* Stanley Smith from the Carboniferous Limestone (D_3) of Siggate, near Castleton, Derbyshire.

TAYLOR, J. S., ESQ., A.M.I.C.E.—Samples of salt deposits and brine from Searle's Lake, West End, San Bernardino County, Cal., U.S.A.

TURNER, G. R., ESQ.—A specimen of silica rock, with analysis.

WAGNER, DR. PERCY A.—Specimen of platinum-bearing hortonolite-dunite from the Lydenburg district, South Africa.

WELCH, F. B. A., ESQ., B.Sc.—Reptilian remains and a specimen of *Oppelia fusca* (Quenst.) from the Chipping Norton Limestone near Stow-on-the-Wold, Gloucestershire.

JOHN S. FLETT,
Director.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1925

I.—INTRODUCTION

Geological Survey Maps

THE principal work of the Geological Survey is the preparation of maps showing the geology of Great Britain on various scales according to the complexity of the geological structure and the economic or scientific importance of the region. This work was instituted in 1832 when Sir Henry de la Beche obtained sanction from H.M. Treasury "to affix geological colours to the maps of Devonshire and portions of Somerset, Dorset and Cornwall." His first maps were ready for publication in 1834, and the work was done under the Board of Ordnance. No previous geological maps had been published in England of any extensive area of country on so large a scale as one inch to one mile. William Smith's great map of 1815 is on the scale of five miles to one inch and Greenough's map (published in 1819) is on the same scale; Macculloch's map of Scotland (1834) is on the scale of four miles to one inch.

The Ordnance Survey had begun the preparation of the one-inch maps of Great Britain in 1797 and by 1830 the whole of the south of England and part of Wales had been completed on that scale. Six-inch maps were not available till 1840, though in Ireland six-inch mapping was begun in 1824. As the Geological Survey maps were merely a geologically coloured edition of the Ordnance Survey maps it was impossible till then to adopt a larger scale. Consequently the whole original survey of the south of England, South Wales and part of the Midlands was carried out on one-inch maps. The north of England, however, and nearly the whole of Scotland, were surveyed from the beginning on maps of the six-inch scale. For nearly seventy years practically the whole of our field mapping has been done on six-inch maps. This enables the geologist to attain great accuracy in the delimitation of boundaries where the field evidence is good, and gives room for many notes on the map itself which would otherwise have to be recorded in note books or by supplementary drawings.

The standard scale for the publication of Geological Survey maps has been the one-inch scale since the Survey was established under De la Beche. This is sufficiently large for all practical purposes except where much mining information has to be inserted; in that case a larger scale is desirable and six-inch maps have been published since about the year 1860. The one-inch scale is too small also for agronomic maps where the country is varied and the agriculture of a highly developed type: the six-inch maps are

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suitable for this purpose because they show every field and every hedge. In pastoral or moorland areas, however, the one-inch maps are all that is necessary.

The general advantages of maps on a scale of one inch to one mile (1 in 63,360), or on a nearly similar scale, have been very widely recognized. The United States publishes many maps on the scale of 1 in 62,500. The standard French map is 1 in 80,000. In Switzerland 1 in 100,000 is the most usual scale, as also in Denmark, Norway, Italy and Sweden. In Austria the most recent maps are 1 in 75,000. In Germany 1 in 25,000 is the scale most widely adopted, but Germany also publishes maps on smaller scales. Many Belgian maps are on the scale of 1 in 40,000.

Probably Great Britain publishes more maps on a scale so large as the six-inch scale (1 in 10,560) than any other country. France and Belgium issue some coalfield maps on the scale of 1 in 40,000. The Prussian coalfields are mapped on the scale of 1 in 25,000. The United States Geological Survey publishes certain maps on the scale of 1 in 10,000. Every country uses the maps which its geographical services have rendered available, thus saving the great cost of preparing topographic plates expressly for geological maps. The advantages to British geologists and mining engineers of having the splendid six-inch maps of the Ordnance Survey available for geological purposes are undoubtedly very great.

Most Geological Surveys publish small scale maps which without exhibiting great detail give a general view of the geology of their country and serve especially for educational purposes. Four maps of this type are issued by the British Survey. The smallest is on the scale of 25 miles to 1 inch. It includes England, Scotland, Wales and Ireland and measures about 3 ft. by 2 ft. This map is very widely used for school classes and general readers, and serves as a handy index map to British geology. It is now in its second edition and has frequently been reprinted.

Maps of England and Scotland on the scale of ten miles to one inch were prepared by Messrs. Bartholomew under the superintendence of Sir Archibald Geikie and issued with Government authority. They are well known to British students and serve their purpose admirably.

The quarter-inch map, on the scale of four miles to one inch, is the most useful map issued for the traveller, motorist and others who wish to obtain a general knowledge of the geology of any part of Britain. The map of England was issued in 1889 to 1896, colour-printed, and was the first colour-printed map made by the Geological Survey of Great Britain. The topography is from Ordnance Survey plates, but the colour-printing was done by a private firm. Parts of it were revised at various dates, but in 1907 to 1913 a new and thoroughly revised edition was published, and the old edition withdrawn from sale. The map is in 21 sheets, each measuring 2 ft. 3 in. by 1 ft. 7 in., and when made up in one map measures 8 ft. by 10 ft., so that it is the largest that can be

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displayed at one time in a class-room or museum. For that purpose an effort has been made to secure uniformity in the colours, and this was fairly successful in the first impressions. The sale, however, is sufficient to call for reprints of individual sheets at intervals and the new impressions do not always match perfectly with adjacent sheets. A certain amount of revision is introduced when new issues are prepared, so that the map is kept up to date as far as possible. New methods of colour-printing are being adopted by the Ordnance Survey in the latest edition of this map, but the colours are to be kept as near as possible to the accepted standard.

A few sheets of this map are issued in drift editions, which are much appreciated for certain purposes, but it has not been possible to prepare a complete drift edition, as in some parts of England the original survey was a survey of the 'solid' rocks only and materials do not exist for a satisfactory drift map.

The quarter-inch Ordnance map of Scotland is in 17 sheets, of which six have been published as 'solid' geological maps: one is engraving and another will soon be put in hand. The incomplete state of this map is due to the fact that certain parts of Scotland are still unsurveyed, *e.g.*, parts of Inverness-shire and Sutherland, the Outer Hebrides, Orkney and Shetland. In Scotland owing to the complexity of the geology this small scale map is less satisfactory than in England as much of the detail has to be omitted.

The one-inch maps of England and Wales exhibit a great variety of states, according to the dates at which they were made and the amount of revision they have received. Some of them are little altered from the original survey work of De la Beche; this holds especially in parts of Somerset, Devon and North Cornwall. The one-inch maps of Bath and Bristol date from 1845, but have received revisions and additions at various subsequent dates. The Barnstaple map (Sheet 27) was made in 1835 and revised in 1839. Much of the south of England was originally surveyed before 1864, and some of the old maps still serve as the basis of the current editions, though in nearly all cases amended and improved. Probably not one of these maps is now issued in its original state.

The geological lines were in those days engraved by hand on copper plates and the maps were hand-coloured, as were all geological maps at that time. Consequently it was not difficult to introduce new boundaries, and only a little more difficult to erase those found to be incorrect. The hand-colouring schemes were modified at a very early date as the survey extended eastwards and new colours proved necessary for rocks not previously shown on the maps. Some of De la Beche's maps, published in 1834, had been modified and partly revised by 1839, and the process was continuous. The late Horace Woodward[1] assembled as full a series of these early maps as could be made some years ago and compiled notes on their

[1] 'Summary of Progress' for 1907 (*Mem. Geol. Surv.*), 1908, Appendix VI, pp. 158-163.

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various 'states,' but the dates and sequence of the changes have not been in all cases cleared up.

Gradually the work of the Survey extended from Devon and Cornwall into South Wales, North Wales, the south and south-east of England, East Anglia and the Midlands. We find for example that Anglesey was published in 1852, Derbyshire 1852, London 1868, Lewes 1864, Hatfield 1867, Ipswich 1882. At first the work was done in the field on the one-inch scale. Field work on six-inch maps, however, was in progress in the sixties of last century and practically universal in the seventies. Some of the current six-inch maps of the Lancashire coalfield bear the date 1860. About 1865 it became clear that the older maps of the south and east of England were seriously defective in respect of the superficial or 'drift' deposits, and a certain amount of revision was undertaken which was not wholly confined to the 'drift' but included also a re-examination of the 'solid' rocks. Thus by 1870 special 'drift' editions of the one-inch maps were making their appearance and the maps of East Anglia, published between 1880 and 1896, are in some cases on 'drift' editions. The 'drift' revision was in many areas done on the six-inch scale, and the whole standard of mapping thus improved.

The maps belonging to the period above described, which may be defined as extending roughly from 1834 to 1885, the first fifty years of the Survey's work, are described as the Old Series one-inch sheets. Many of them are still on sale, though a large number have been replaced by New Series maps. The Old Series maps are all engraved on copper, hand-coloured, with the old topographical basis belonging to the period at which they were issued. Although some of them are much out of date (as in North Wales for example) many of them have received alterations at several periods and are still of use in districts where the geology is not very complex as in Essex and Norfolk. The area they cover extends from the south coast to about the latitude of the Humber estuary.

The one-inch maps of the northern counties of England are based on the New Series Ordnance maps. The boundaries of these are the same as those of the Old Series which they replaced, but all the maps are obtainable in quarter-sheets, while some of the Old Series maps are on sale only in whole sheets. The change from Old Series to New Series has not a very great significance as regards the methods of geological mapping. Continuous progress had been going on by the introduction of greater detail both in solid and drift, rendered possible by the use of six-inch maps in the field. The methods of reproduction also were not altered. Engraving by hand on copper plates and hand-colouring were still in vogue up to the year 1896. This produced often a very beautiful map, with clean-cut lines, and transparent coloration. It was possible also to introduce changes very quickly if errors were detected, and the numerous though slight revisions show that advantage was taken of this. But the work was costly and slow, and errors in hand-

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colouring could not be avoided. No other Survey adhered to these methods so long as the British Survey and by 1900 it became clear that at all events the smaller-scale maps should be reproduced by mechanical processes.

The first one-inch colour-printed maps issued by the Geological Survey were probably the Chichester (317) and Ringwood (314) Sheets published in 1902, and the special London map in four Sheets published in 1903. Of the New Series colour-printed one-inch Sheets 135 have now been published and 25 are in various stages of preparation. Their dates of publication are from 1902 onward. The number of topographical sheets of this series published by the Ordnance Survey for England and Wales is 360. This means that approximately one-third of England and Wales is now available in revised colour-printed one-inch sheets and two-thirds are still published on hand-coloured sheets of various ages and forms. The oldest one-inch sheets now on sale are from North Devon, where some of them bear the date 1839.

Each of the New Series sheets measures 24 in. by 18 in. and represents 216 square miles of country (including areas of sea or lakes). Many of the sheets in addition to an index of colours and symbols have a vertical and horizontal section drawn to scale. Some of these maps are issued only in 'drift' editions, specially those of the south of England, London district, Cornwall and the East Riding. 'Solid' editions of the maps of coalfields on the other hand are usually published in addition to 'drift' editions ; this is the case in South Wales and the Midlands. Special maps have been published of London, the Isle of Wight, Anglesey, Nottingham, Oxford and the Isle of Man. As far as possible uniformity in colour schemes and in symbols and notation has been maintained in this series, and adjacent maps usually harmonize, though never completely. The methods of colour-printing have been modified as experience warranted. The earlier maps were reproduced by lithographic processes, often involving from twenty to thirty separate printings. Methods of 'six colour' printing requiring only seven or eight printings are now being employed with sufficiently good results and a great saving of time and expense. The engraving, formerly done by hand, is now generally executed by photo-etching from drawings specially prepared.

The New Series colour-printed one-inch maps have in nearly all cases been throughly revised before publication. This is especially true of the coalfield areas, where accuracy is of great importance and new information rapidly accumulates owing to mining and boring operations. These coalfield maps are based on a thoroughly complete re-survey on the six-inch scale (except one or two sheets in the Midlands). In agricultural districts, however, the old original survey with its subsequent partial revisions has been made use of wherever sufficiently good, and its defects have been repaired by local re-surveys on the six-inch scale ; examples of this are

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Marlborough (266) and Brighton (318) recently published. The whole London area has been very thoroughly revised on the six-inch scale, as for building and residential purposes the demands for information are very frequent.

When in 1896 the original survey of England and Wales had been completed and systematic revision was begun it was decided to give preference to coalfields, mining districts and densely populated areas. Hence the first areas re-surveyed were South Wales, South Cornwall and Devon, the London area, and the coalfields of the Midlands; the new maps of these districts are now published. Some other areas of which the Old Series maps were satisfactory have also been issued in colour-printed form. These include the Hampshire basin, the Isle of Wight, the Isle of Man and the East Riding of Yorkshire. In 1920 it was decided to start revision of Northumberland and Durham, Cumberland, Lancashire and West Yorkshire, and the first colour-printed maps of these districts are now coming from the press. As a consequence of this programme the areas represented on these new maps are widely scattered. The south of England has received most attention and if we draw a line from Pembroke to Clacton-on-Sea about two-thirds of the district south of that line has been published colour-printed. Of the Midlands and North Wales few colour-printed maps are yet available (except for coalfields) and in the north of England only the East Riding is well represented in this series. But at present the new publication is scattered fairly evenly over the whole country and every district is receiving attention, though the coalfields have preference.

The original series of six-inch maps of English and Welsh coalfield and mining areas began to appear about 1860 and was completed about 1895. The districts represented were Yorkshire, Lancashire, Cumberland, Northumberland and Durham. The sheets were issued as whole sheets, representing 24 square miles of country and they were engraved on copper and hand-coloured. Many of these old sheets are beautiful examples of geological cartography. As the districts they represent are not yet completely revised on the six-inch scale most of these old sheets are still on sale, but in each of the coalfields above mentioned the new six-inch survey is beginning to be published.

When six-inch revision was started those coalfields of which only one-inch maps had been hitherto made were given preference. In addition to the mining districts of Cornwall and Devon (of which only a few new six-inch sheets have been issued), the coalfields of South Wales, Leicestershire, Warwickshire, North Staffordshire, Cheadle, Nottinghamshire and North Wales have been revised and published on the six-inch scale. Revision of all the other English coalfields is in hand except Bristol and Somerset, Forest of Wyre, Forest of Dean, and the Clee Hills.

The new six-inch maps are published in quarter-sheets each representing six square miles of country and measuring 18 in. by

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12 in. Their topography is always the latest available, and as new topographical editions appear the geological information is usually transferred to them. These maps are not engraved on copper but are reproduced by heliozinco methods; consequently their lines and notes are not so clear and sharp as in the older six-inch maps but they are far less costly and equally serviceable. Many of them have a vertical measured section showing the sequence and average thicknesses of the strata occurring in the area they represent. These sections are of great importance as they furnish very necessary information for the interpretation of the map. About 456 of these revised quarter-sheets have now been published; about 215 of the old whole sheets are still on sale, but many of them have been published in revised editions, though not completely re-surveyed. These old sheets bear various dates from 1860 to 1895. Usually forty or fifty English quarter-sheets are being engraved or corrected for the press each winter and an equal number are being standardised and prepared for engraving.

The new six-inch maps are on sale not only in the coloured but also in uncoloured state. Originally this was not done but about twenty years ago it was found that uncoloured copies were desired for certain purposes. It now appears that the sale of uncoloured six-inch maps is very much larger than the sale of coloured maps, and consequently all Survey maps may be purchased in uncoloured state. They are of course very much cheaper, as hand-colouring is necessarily expensive, but by free use of index letters and symbols the maps are perfectly intelligible without colour. All Survey maps are now prepared so that they can be thoroughly understood in the 'plain' state. Many students and teachers like to colour their maps for themselves, and engineers, architects, surveyors and mines managers have skilled draughtsmen who can colour their maps by any system they find desirable. Often they require only part of a map to be coloured or wish to use a scheme of colours different from the standard schemes of the Survey. Very few Geological Surveys issue uncoloured maps and probably no Survey sells so many uncoloured maps as the Geological Survey of Great Britain.

The Geological Survey of Scotland began in 1854 under Sir Henry De la Beche and the Edinburgh Sheet was published as early as 1859. By this time the English Survey had been at work for 20 years and its methods of surveying and of publication were well established. Six-inch maps were available almost from the start in Scotland and there has been very little original work done on the one-inch scale except for a brief experiment in the Highlands. In Scotland also there has been only one series of one-inch maps. so that the Sheet numbers and boundaries have never been changed, though the topographical details have frequently been revised. Up to 1910 all the one-inch sheets were hand-coloured and there were no drift editions except of Sheet 45 (Loch Awe), Sheet 55 (Aberfeldy), and of 13 and 21 (North and South Arran). In 1910, however, the Glenelg Sheet (71) and a special sheet of Arran, were

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colour-printed. In England colour-printed one-inch maps were being issued in 1902. The delay in adopting colour-printing in Scotland was due to the great complexity of the geology, which required a very large suite of colours and would entail great expense if printed by ordinary lithographic methods. At the suggestion of the Director-General of the Ordnance Survey, however, a modified six-colour method was tried and proved fairly satisfactory. This method was gradually improved and has now been extended to the English one-inch sheets, though it is considerably modified in many details. Since 1910 no new Scottish one-inch map has been published hand-coloured, and some of the earlier maps have been replaced by colour-printed editions.

The Scottish maps differ from the English maps in their methods of representing drift. Only one special colour-printed drift map has yet been published (Sheet 31, Falkirk); all the others represent the solid rocks by colour, and the drift by stipple of black dots, circles and other patterns overprinted on the solid. This method is quite satisfactory in districts where the topographical detail on the map is not heavy, as in the Southern Uplands and the Highlands. In coalfields and densely populated districts where there are many geological lines and much topographical detail the overprinted stipple obscures the map and it has been decided to issue special drift editions, as in England.

The recent Scottish one-inch sheets have vertical and horizontal sections drawn to scale, on their margins, except in the Highlands.

The colour-printed Scottish maps also are larger than the English. They measure about 31 in. by 25 in. and represent 432 square miles of country (inclusive of sea and lakes where present). The Ordnance Survey one-inch map of Scotland is in 131 sheets. Of these 93 have been surveyed, 39 are published in colour-printed form, and 54 hand-coloured maps are on sale (of which 7 are being prepared for colour-printing). Some of the unsurveyed sheets represent only islands of insignificant extent and it is estimated that about one-fifth of the land area remains to be surveyed; of the ground already surveyed one-half will have been colour-printed by the end of 1927. Some of the original colour-printed sheets are now being prepared for a second edition.

The whole of the coalfields of Scotland have been published on the six-inch scale, and in addition to this a few six-inch maps of districts of special geological interest in the North-West Highlands and in Skye have been issued. The old series of coalfield maps though not always rich in geological detail were excellent from a cartographical standpoint and have served their day very well. They are now being rapidly replaced by new six-inch quarter-sheets which do not differ materially from those which are being issued in England. The 'List of Memoirs, Maps, Sections, &c.' published in 1925 shows that 232 new Scottish quarter-sheets were on sale and 50 of the old whole sheets had not yet been superseded, mainly in Fifeshire, South Ayrshire, and Dumfries-shire; but about 30

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quarter-sheets have been issued since that list was prepared. In all probability the first six-inch revision of Scottish coalfields will be practically completely published by the end of 1928. In some districts, such as the oil-shale fields of the Lothians, a second revision of certain sheets has been published. The new maps carry abundant details about coal-seams, ironstones, fireclays, records of bores, etc. At the same time new solid and drift editions of the one-inch maps of the Scottish productive Carboniferous are to be published. Several of these have already appeared, viz., Haddington, Edinburgh, Falkirk, Glasgow, and others are in preparation, viz.. Kilmarnock, Ayr, Lanark and Peebles.

JOHN S. FLETT.

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II.—FIELD WORK

(A)—ENGLAND AND WALES

1. LONDON AND SOUTH-EASTERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.Inst.C.E.
F. H. EDMUNDS, M.A.
WILFRID EDWARDS, B.A. } Geologists.

Work in the London and South-Eastern District was concentrated upon the area in Sheet 285 (Aldershot), with the exception of some minor revisions of the Lewes map (Sheet 319). Beyond the limits of the South-Eastern District Mr. Dines was engaged upon the revision of the mining information contained in the Land's End memoir in preparation of a second edition. Mr. Edmunds spent two months in the early spring visiting Wiltshire to collect information with reference to wells and borings for the recently published memoir on the Water Supply of that county. Mr. Edwards was temporarily transferred from Yorkshire to undertake similar work for a memoir on the Wells and Springs of Dorset. All the arterial road sections were visited by Mr. Dines, who wrote reports on the Watford, the Sidcup and Bexley Heath and the Grays sections. Mr. Edmunds examined the beds of fuller's earth in the Weald Clay recently discovered near Baynards (Sheet 301).

Mr. Dewey was engaged upon the following memoirs which were published during the year:—Special Reports on Mineral Resources, Vol. XXX, 'Copper Ores of the Midlands, Wales, the Lake District and the Isle of Man'; 'The Geology of North London' (Sheet 256); 'The Geology of Romford' (Sheet 257); and 'The Geology of Marlborough '(Sheet 266). Colour-printed maps of Sheets 256, 257, and 266 were also published. During the spring Mr. Dewey visited the Lewes district to revise certain boundaries on Sheet 319: the map has been engraved and will shortly be published. He also visited Oxford to inspect the Pleistocene deposits in connexion with the chapters dealing with these beds in the forthcoming memoir on Oxford. A large part of Mr. Dewey's time has been taken up in replying to numerous enquiries with regard to water supply, and sites for buildings, railways and docks in the South of England; and with reference to mines and minerals in Cornwall and Devon. We are indebted to Mr. Davison, of Camborne School of Mines, for much information relating to recent developments in the mines and for details of shaft and road sections.

The thickness of the London Clay and of the overlying gravels and alluvium has an increasingly important bearing upon engineering problems, and numerous enquiries have been dealt with relating to these deposits.

The new housing schemes have raised questions as to sewage disposal and water supply in the areas concerned, and also in areas to which the richer residents have removed as a result of the

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The Devil's Den, Sarsen Stones, near Fyfield.
[Taken from the Geological Survey memoir on 'The Geology of the Country around Marlborough,' 1925.]

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destruction of the amenities of the former outer suburbs. The Weald is becoming a favourite residential district, but a serious difficulty is the inadequate water supply from the Wealden formations. The larger towns are seeking fresh reserves of underground water, often in areas far removed from their precincts. Contamination by Thames water is spreading in parts adjacent to the river in east and south-east London, and the existing bore-holes are being deepened to cut out the contaminated water.

ALDERSHOT SHEET

In the areas around Guildford, Farnborough, Aldershot, and Farnham, Messrs. Dines and Edmunds have mapped Cretaceous, Tertiary and later deposits. The distribution of the Bargate Beds has been indicated on the new maps.

An important result of the re-survey has been the recognition of a series of strike faults in the Cretaceous rocks, some of considerable throw. Mr. Edmunds has found a deposit in which numerous wind-facetted fragments (Plate II) of ferruginous sandstone occur, but at present is not able to assign a period when this action was operative.

Mr. Edmunds has ascertained that the dominant structural feature of the area between Guildford and Godalming is the Peasemarsh Anticline, an east and west fold, as described by Topley,[1] with a steep northern and gently sloping southern limb. The southern limb is flexured by subsidiary folds.

An inlier of Atherfield Clay is exposed around Shalford and Littleton, where it appears in the core of the Peasemarsh Anticline. The Clay is exposed also south of Shamley Green and in two small inliers at Shamley Green and Thorncombe Park respectively.

Mr. Edmunds has mapped the Hythe Beds, on the north of the Peasemarsh Anticline, from Compton to Chilworth, and notes that they cover a wide area around Godalming, where they consist of grey and brown sands and loams, often glauconitic, with thin seams of sandstone. The stone increases in thickness eastwards. A boring for the proposed sanatorium at Tuesley, south of Godalming, commenced in beds lying near the top of the Hythe Beds, and the following strata were proved[2]:—

	Thickness Ft.	Depth Ft.
Soil	1½	1½
Loam	6½	8
Sand	5	13
Stone	3	16
Sand, with thin layers of stone	19	35
Stone	7	42
Sand, green and glauconitic	37	79
Sand, dark grey	29	108
Sand, brown, and sandstone	30	138
Undescribed	20	158
Atherfield Clay	—	—

[1] 'The Geology of the Weald' (*Mem. Geol. Surv.*), 1875, pp. 229–232.
[2] From a record by Messrs. C. Isler and Co.

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The Bargate Beds, consisting chiefly of strongly current-bedded calcareous sand and sandstone, were formerly included with the Hythe Beds but have now been mapped as a separate division. In thickness they vary from 20 ft. to 40 ft., but locally thin out and become absent. Along the northern limb of the Peasemarsh Anticline the outcrop from Compton to Chilworth is narrow, rarely exceeding 25 yds., as the beds dip approximately at 12°.

Around Godalming the outcrops are broad, most of the high land consisting of the Bargate Beds, which, although nearly horizontal, rise slightly southwards from Bramley and dip also southwards towards Tuesley. The Bargate Stone is used locally for buildings, the stone suitable for this purpose being generally in the form of large lenses or 'doggers' lying in sand, and known colloquially as 'builders.' Those lying near the surface are often weathered, and split readily along the planes of the current-bedding into 'Flat Stones,' for which there is a big demand at present for use in crazy pavements. The seams and doggers of partly cemented sand are known as 'Joel Stone.' Towards the base the rocks are pebbly and phosphatic and are exposed in a large quarry three-quarters of a mile south of Godalming church. Similar rocks occur in the Minster quarry, half a mile north-west of Busbridge Hall, but both quarries are unworked.

In Blackheath Lane, south of Albury, a seam of oolitic sandstone, 2 ft. thick, occurs. The grains of oolite are corroded and the quartz grains are not coated with lime. A similar rock was recorded south of St. Martha's,[1] and the corroded state of the oolite grains was then attributed to their derivation from a pre-existent rock of Upper Jurassic age. Southwards and eastwards the Bargate Beds thin out rapidly. Although they are not found at Blackheath, they appear to be represented by a seam of brown clay, about a foot thick, overlain by pebbly sand. This seam was first observed in a large disused sand-pit, half a mile east of Great Tangley Manor House. Originally the face of the pit was about 20 ft. in height, the clay and pebbly seams lying about 6 ft. from the top, at a height of a little over 300 ft. above O.D.

The Folkestone Sands throughout the district consist of one lithological type, ferruginous quartzose sand, with irregular seams, rarely more than 3 in. thick, of ferruginous sandstone (Carstone). The sands are often current-bedded, a feature well seen in a pit 200 yds. northward of the level-crossing on Albury Heath. Mr. Edmunds notes that Folkestone Beds extend from Compton to Albury, and occur around Blackheath. Outliers have been mapped at Farley Hill and Munstead Heath, Charterhouse, Chinthurst Hill and Barnett Hill, about half a mile east of Wonersh.

Mr. Dines has mapped the Folkestone Sands south of Seale and between Hampton Park and Moorpark, also along the north bank of the Wey through Farnham. A pit near Larchfield House

[1] Chapman, F., *Quart. Journ. Geol. Soc.*, vol. l, 1894, p. 677.

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shows 10 ft. of current-bedded yellow sand resting on 4 to 5 ft. of pebbly red loam with seams of clay. The pebbles are small, rarely exceeding 1½ in. in diameter, and consist of quartz, lydite, polished ironstone and chert possibly derived from the Hythe Beds.

The Gault first appears near Runwick House and thence follows the north bank of the Wey eastwards to High Mill. It is displaced by faults near High Mill and at Runfold; beyond Runfold it extends eastwards along the lower slopes of the Hogs Back and is faulted twice near Great Down. It has been traced by Mr. Edmunds as far as Albury. There are only two exposures, one in the railway cutting near Runfold and the other near the southern fence of Farnham Park. At the latter place a strike fault throws it against the upper part of the Lower Chalk. At least 152 ft. of Gault were penetrated in a well at the Waterworks, west of Castle Street, Farnham.[1] The thickness of the formation to the south of the Hogs Back is estimated to be between 170 ft. and 190 ft.

Mr. Dines has followed the Upper Greensand from the western edge of the district to Farnham, where it forms a wide outcrop, but east of Farnham, on account of the increased dip of the beds, the outcrop narrows rapidly to a width of about 50 yds. From Farnham Castle to a quarter of a mile east of the Workhouse the formation appears to have been cut out by a strike fault which throws the Chalk down against the Gault. It reappears in the railway cutting, a quarter of a mile north of High Mill; it is faulted near Runfold, but forms a continuous band about half way up the scarp face of the Hogs Back as far as Great Down, where there are two small faults. Its thickness appears to range from 60 to 85 ft.

Mr. Edmunds has traced the outcrop from Compton to Artington, and, east of the Wey valley, from Warren Farm, Guildford, to Albury. The rock is clearly exposed 100 yds. north of Conduit Farm, two miles west-south-west of Guildford, where there is a section in a small quarry of 3 ft. of hard, grey, slightly calcareous sandstone containing fossils. Lumps of similar rock are ploughed up eastwards of Tyting Farm, south-east of the town. The outcrop averages 50 yds. in width.

Until the detailed examination of the fauna has been completed but little can be said of the zones of the Chalk. The outcrop has been mapped by Mr. Dines from Dippenhall to Whitelane Farm; he states that the general dip along the Hogs Back ranges from 40° to 45° north. The Cuvieri Zone is exposed in the northern cliff of the Seale Limeworks quarry: the east face also exposes this zone separated by the Plenus Marl from the zone of *Holaster subglobosus*. The dip here is about 43° north. In a sunk road south of the pit marly chalk of the Varians Zone is exposed. The full thickness of the massive Terebratulina Zone is seen in the more northerly pit behind the Victory Inn, south-west of Poylehill House, overlain on

[1] 'The Water Supply of Surrey' (*Mem. Geol. Surv.*), 1912, p. 162.

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the north by chalk of the Planus Zone, while the nodular Cuvieri chalk outcrops on the south. In the southern pit the Lower Chalk forms most of the section, with the Plenus Marl in the north face.[1]

West of the Runfold Fault the Chalk occupies the low ground at the foot of the Tertiary escarpment, where the upper reaches of the Blackwater river flowed before they were captured by the Wey. The Chalk on account of its low dip does not form a pronounced escarpment west of Farnham. Beneath the south fence of Farnham Park a section in an old pit proves the westward continuation of the strike fault seen in pits near Badshotlea[2]; the hard grey chalk of the Subglobosus Zone is faulted against the Gault, while the Upper Greensand and the Chalk Marl are absent.

About a quarter of a mile east of Farnham Workhouse a transverse fault throws down the Chalk to the east.[3] A spring rises at the foot of a small cliff in the east bank of the Bourn Mill Stream, half a mile south of Hale. Gravel in the pits on the east side of the stream is rendered difficult to work on account of heavy water which wells up from the underlying Chalk ; the gravel pits on the west are dry. This difference is probably due to the faulted state of the Chalk. It is notable that this fault is in alignment with the Waverley section of the River Wey.

Mr. Edmunds has observed a series of strike faults west of Guildford. He has traced the Thanet Sand as far west as Hatchlands, West Horsley. In the south-eastern corner of the park a small pit exposes three feet of fine buff sand. Opposite the south-eastern gates of the park a small cutting on the south side of the road shows three feet of similar sand with nine inches of the Bull Head Bed resting on an eroded surface of chalk. In a well at Horsley Towers eight feet of Thanet Sand was proved at a depth of 25 ft. from the surface.[4]

The Reading Beds outcrop at the base of an escarpment of Tertiary beds west of Farnham, while east of Runfold they lie to the north of the Chalk escarpment and form low ground. They are affected by the two faults near Runfold. Thence eastwards they form a continuous narrow outcrop through East Horsley. An outlier consisting of glauconitic sandy clay has been observed by Mr. Edmunds northward of Netley Heath. Generally the beds, where exposed, consist of variegated and mottled clay with a fairly continuous seam of sand near the junction with the London Clay. The boundary line, however, is difficult to trace on account of hill-wash, but a bed consisting mainly of shells of *Cyrena* was exposed in an overflow channel from the southern ornamental pond in Clandon Park.

Mr. Dines finds that the thickness of the London Clay near Aldershot is fairly constant and attains 330 ft.[5]: it is 65 ft. thinner

[1] Young, G. W., *Proc. Geol. Assoc.*, vol. xx, 1908, p. 449.
[2] Young, G. W., *op. cit.*, p. 435.
[3] Young, G. W., *op. cit.*, p. 434.
[4] 'The Water Supply of Surrey' (*Mem. Geol. Surv.*), 1912, p. 155.
[5] Lyons, H. G., *Quart. Journ. Geol. Soc.*, vol. xliii, 1887, p. 441.

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than at Brookwood.[1] No trace of the Claygate Beds was found, but the surface of the London Clay was seen to have been eroded in a brick-pit near Aldershot.[2]

The Bagshot Sand forms an extensive tract from the Blackwater valley to Hog Hatch and Warren Corner and northwards to Ewshott. The general dip appears to be about 3° N. by E., while a gentle easterly tilt is shown by the base falling from a height of 370 ft. above O.D. at Warren Corner to 230 ft. in the Blackwater valley.

A conspicuous basal bed, 10 to 12 ft. thick, of interbedded yellow sands with dark grains and red loam resembling brick-earth is exposed in the railway cutting near Aldershot Station, and in an old brickyard about half a mile to the south-west of the cutting. The nature of this basal bed closely resembles some of the Bracklesham Beds, and from this fact Dr. Irving concluded that an unconformity cut out the whole of the Bagshot Sand and the lower part of the Bracklesham Beds.[3] This conclusion was found to be erroneous,[4] the Bagshot Sand having been proved in borings at Aldershot to attain a thickness of over 100 ft.

South of the Royal Pavilion the Bagshot Sand is brought to the surface by an anticline with an east to west axis, which is approximately the direction of strike of the beds. This fold extends westward to the Rifle Ranges below Cæsar's Camp. A small area of Bagshot Sand at Ayling Hill has been lowered by a land-slip into the valley of the Blackwater near the source of the river.

The three main divisions of the Bracklesham Beds which occur with regularity over the Bagshot district[5] appear to die out southwards. Mr. Dines has not been able to find any regular succession of beds but notes that three lithological types may occur at any horizon, namely, lilac clay laminated with ochreous sand, yellow sand distinctly current-bedded and divided by seams up to 8 in. thick of red loam, with laminated pipe-clay, and glauconitic green sand with seams of variegated plastic clay: worm borings infilled with green sand are of common occurrence in this clay.

The base of the Barton Sand was represented on the Old Series geological map at Yateley Common just below the level of the 300-ft. contour, apparently because glauconitic sand is exposed at a similar level in a road cutting a quarter of a mile west of Hawley. But the railway cutting half a mile north of Hawley exposes yellow sand of the same lithological characteristics as the Barton Sand, at 218 ft. above O.D. A series of trial borings was therefore sunk between the two exposures, and these proved the occurrence of yellow sand over the whole area; the glauconitic sand is probably of only local

[1] 'The Water Supply of Surrey' (*Mem. Geol. Surv.*), 1912, pp. 257–259.
[2] Irving, A., *Quart. Journ. Geol. Soc.*, vol. xli, 1885, pp. 500, 501.
[3] *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 501.
[4] Monckton, H. W., and R. S. Herries, *Quart. Journ. Geol. Soc.*, vol. xlii, 1886, p. 402; also H. G. Lyons, *op. cit.*, vol. xliii, 1887, p. 435.
[5] Warburton, H., *Trans. Geol. Soc.*, ser. ii, vol. i, 1824, pp. 48–52; A. Irving, *Quart. Journ. Geol. Soc.*, vol. xli, 1885, p. 492; 'The Geology of Windsor and Chertsey' (*Mem. Geol. Surv.*), 1915, p. 41.

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occurrence. The base of the Barton Sand has accordingly been taken below the level of the railway cutting at about 210 ft. above O.D. to correspond with its position in the area east of the Blackwater.

Near Ively Farm a temporary excavation proved the Barton Sand; the outlier east of Fleet Pond therefore extends as far as this locality.

South of the Basingstoke Canal the basal beds along the northern slopes of Beacon Hill and Cæsar's Camp throw out a line of springs and seepages at a level of 550 ft. above O.D.; the water from these is collected in launders of semi-circular glazed ware and conducted to a lateral launder following the contour of the hill to the reservoirs in Bourley Bottom. The supply averages 300,000 gallons per day.

Road widening sections have shown that the outlier near Stanhope Lines does not extend, as formerly supposed, along the crest of the escarpment between Rushmoor Green and the cemetery.

Messrs. Dines and Edmunds have traced the boundaries of the High Level Gravels. The tracts at Cæsar's Camp, Beacon Hill and Hungry Hill attain a thickness of 12 ft. to 15 ft. and are overlain by 6 ft. to 8 ft. of stony loam. The surface level is rather over 600 ft. above O.D. in the ground lying north of the Odiham road, but inclines southwards. An abnormal thickness of nearly 30 ft. of gravel without loam occurs about a third of a mile west by south of Lawday House, but this thick gravel is of local occurrence only and appears to represent an infilled channel. Towards Upper Old Park the level approaches the 500-ft. contour, where the gravel is about 6 ft. thick.

Battered or noded nodular flints, in part retaining their cortex, are the principal components of the gravel; they are interbedded with coarse yellow sand, smaller numbers of pebbles from Tertiary beds, and small quartz pebbles and chert from the Lower Greensand. Locally a ferruginous cement binds the pebbles into a hard conglomerate, as in a disused pit on Beacon Hill, where a mass 2 ft. in thickness projects from the working face. It is conspicuous north-east of Cæsar's Camp, where two fallen blocks 8 ft. in thickness form the 'Jock and Jenny Stones.' Coarse sandy loam, including festoons and pipes of gravel consisting of battered and fractured flint, covers the plateau. All these tracts lie on Tertiary beds. A small area occurs at Crooksbury Hill at a height of 530 ft. above O.D., where ironstone fragments compose about half of the gravel. The flints are angular and mostly about 1 in. in diameter, but many attain 5 in., and there are pebbles of white quartz and lydian stone. This gravel rests on the Folkestone Beds. Mr. Edmunds has mapped large-flint gravel on the north side of the Chalk hills which extends from Newlands Corner to Netley Heath. The age of these gravels has long been suspected to be Pliocene, and evidence is accumulating, mainly from their heavy mineral constituents, to substantiate this contention.

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Plateau gravel has been traced by Mr. Dines at Yateley Common, where it lies at 330 ft. above O.D., and also at Thorn Hill, east of Stanhope Lines, at 360 ft. Some tracts at Pondtail Farm, Miles Hill and in the Long Valley appear to owe their origin to wash from the higher tracts at Cæsar's Camp and Beacon Hill.

In the portion of the Blackwater valley between Ash Vale and York Town only two gravel terraces were observed.[1] Westward of York Town, however, there are three well-marked terraces resting respectively at heights of 0 to 10 ft., 25 to 40 ft., and 70 to 80 ft. above the present river-level, the middle of the three terraces corresponding in height with the higher of the two that occur above York Town.

Spreads of gravel lie on the northern slopes of the Wey valley around Farnham. They form terraces at varying heights up to nearly 200 ft. above the river, and appear to correspond with those into which the gravels on the opposite side of the valley were divided by Mr. H. Bury.[2] From the evidence of the contained palæolithic implements Mr. Bury correlated three terraces, situated at about 150 to 130 ft., 90 ft. and 50 ft. above the river, with the Boyn, Taplow and Flood Plain terraces respectively of the Thames valley. These terraces, which now flank the Wey above Farnham, were deposited by the Blackwater before the capture of its head-waters by the Wey at a point north of Culverlands,[3] the lowest terrace being in process of formation at the time of capture.

Mr. Edmunds notes that river gravels of streams tributary to the River Wey occur in several localities. The most interesting are gravels of four valleys commencing at the northern boundary of the Chalk and running northward to the River Wey.

These valleys commence at Merrow, Clandon Park, West Clandon, and East Horsley respectively. The Clandon Park valley is now completely dry, while the other three have small streams which have cut below the level of their original valleys, leaving there a terrace about 8 or 10 ft. above the present stream-level. This is particularly well seen near Ockham in the stream from East Horsley.

The broad spread of gravel at the Pease Marsh district of Shalford, partly belonging to the River Wey and partly to a small tributary from Compton, and spreads at Wonersh, Shamley Green, and in the valley between Blackheath and Farley Heath have also been traced.

Over the area west of Farnborough, between Cæsar's Camp and Yateley Common, there has recently been extensive denudation. The Barton Sand has been eroded over most of this area, and only thin outliers of it, generally gravel-capped, remain. Between Brooke House and Whitehouse Farm and at Cove Common there are large flat tracts of swampy, peaty ground which merge almost imperceptibly into the alluvium of the Cove Brook, the stream flowing past Cove. These low tracts correspond in level with that

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 36.
[2] *Proc. Geol. Assoc.*, vol. xxiv, 1913, p. 178, *et seq.*
[3] *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 318, *et seq.*

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of the adjacent parts of the floor of the Blackwater valley, from which they are separated by higher ground capped by middle terrace deposits, as, for example, at Farnborough.

Ill-defined tracts of hill wash gravel lie in low areas, as at Fleet Pond, and also as cappings to the low hills of Barton Sand, as at Pondtail Farm and in the Long Valley. They have been classified as 'undifferentiated valley gravel' and 'plateau gravel' according as to whether they are situated in a valley or upon elevated ground, but there can be but little doubt that they are later, at least, than the highest terrace of the Blackwater.

The process of erosion is well shown in Long Valley. The stream flowing in Claycart Bottom has divided the Barton outlier in Long Valley into two, and now flows at its base-level of erosion over clays and loams of the Bracklesham Beds. About a quarter of a mile to the west of Claycart Bottom, and almost parallel to it, another stream drains the Bracklesham country around Jubilee Hill, but flows only after heavy rains. This stream has cut through the gravel cap of the western outlier in Long Valley, and flows in an incised channel some 8 ft. deep in the Barton Sand. It is rapidly widening its course by undercutting its banks and is thus effectively planing off the Barton Sand outlier. The tributaries which drain the surface of the gravel afford an example of the small amount of resistance offered to erosion by the Barton Sand. While flowing across the gravel surface they produce only small furrows, but on reaching the edge of the gravel the streams plunge into pot-holes 6 or 7 ft. deep, the sides of which continually collapse and the valley is thus cut back upstream.

Smallshot Hill, a quarter of a mile north-west of Camp Farm, was a steep-sided more or less conical hill, formed of Barton Sand protected by gravel, which rose some 50 ft. above the level of the surrounding Bracklesham Beds. The spot was selected as the site for a military camp, but as the steep slopes of the hill formed an obstacle to the effective lay-out of the buildings, the upper 35 ft. have been removed and brought to the level of the lower ground of Smallshot Bottom, to form an area of gentle gradients. The process of levelling has not only modified the landscape but also has obliterated the small spread of gravel shown on the geological map.

Wind blown deposits.—An interesting discovery on the high ground around Godalming has been that of wind-facetted pebbles (Plate II) consisting of 'Carstone' derived from the Folkestone Sands. The high ground in this district is capped by Bargate Beds, which here are almost horizontal, with outliers of Folkestone Sands remaining in places. Resting on the Bargate Beds is a brown sandy drift, up to two and a half feet in thickness, on the surface of which, or bedded in it, these pebbles lie. They were first noted at Foxburrow Quarry, Bramley, where the pebbles are irregularly dispersed throughout the two and a half feet of drift at the top of the quarry, and later were found in large numbers in the ploughed fields around Godalming. HENRY DEWEY.

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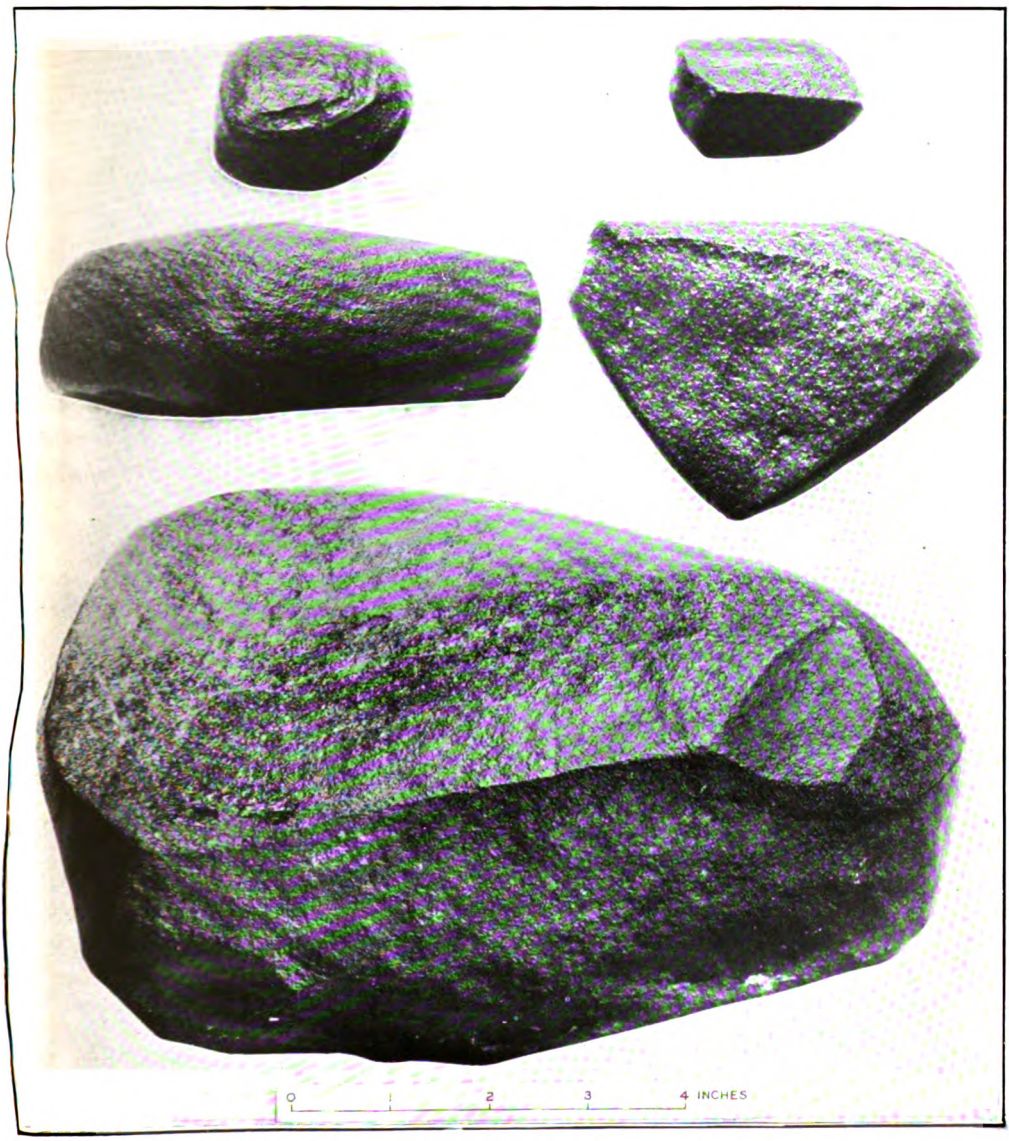

Wind-facetted pebbles of Carstone from Godalming.

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2. MIDLAND DISTRICT

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T. ROBERTSON, B.Sc., Ph.D., A.Inst.M.M. }

DURING the past season work has been continued in the Shrewsbury Sheet (152). The revision of the Stafford Sheet (139) has been completed, and so much of the Burton-upon-Trent Sheet (140) has been mapped as was necessary to finish the Stafford Sheet.

In the first-named, Mr. Pocock carried on the surveying of the Pre-Cambrian, Cambrian and Carboniferous formations around Little Wenlock and the Wrekin. In Sheets 139 and 140 Messrs. Pocock and Whitehead completed the examination of an area of Triassic rocks, with various superficial deposits, lying between Stone and Hilderstone and extending thence southward through the town of Stafford to Acton Trussell.

Dr. Robertson has investigated the section provided by the new Colwall Tunnel through the Malvern Hills.

Pre-Cambrian.—The mapping of the Uriconian rocks, which form the main axis of the Wrekin, has been commenced by Mr. Pocock, and some preliminary work has been done on the Rushton Schist to the west.

Cambrian.—The Wrekin Quartzite, the base of the Cambrian system of Shropshire, has been mapped by Mr. Pocock along the south-eastern flank of the Wrekin from Lawrence Hill in the north-east to Little Hill (Primrose Hill) at the south-west end of the range.

At Lawrence Hill (Fig. 1, p. 44) the quartzite, with a basal breccia containing Uriconian fragments, rests at a low angle on the Uriconian. It is cut by a strike fault, to the south-east of which the dip is much steeper, averaging 40°.

Along the main outcrop of the quartzite on the south-east side of the Wrekin the dip varies between 40° and 70°. Mr. Pocock estimates the thickness of the quartzite here at about 140 ft. At Little Hill the strike changes and the outcrop trends westward to Rushton Cottage, where it is cut off by the Wrekin Fault, an important fracture ranging north-eastward along the north-western flank of the Wrekin.

North-west of this fault the quartzite is seen again above Wrekin Farm (Fig. 2, p. 45), where the mapping has shown that it rests unconformably, with gentle south-eastward dip, on the Uriconian, and that it is cut off on the south-east by the fault, which, at this locality, appears to have a throw of about 600 ft. The base of the quartzite is marked, as at Lawrence Hill, by a breccia containing fragments of the underlying Uriconian rocks.

For a little over a mile south-westward of the rifle-range near

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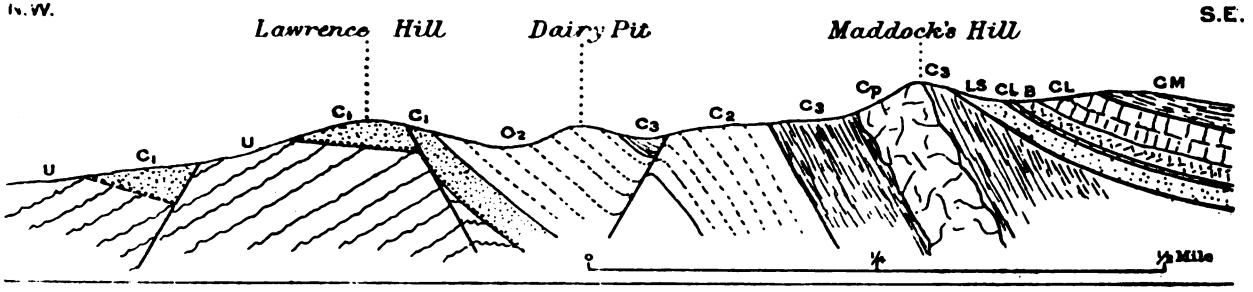

FIG. 1.—*Section across Lawrence Hill and Maddock's Hill.*

CM = Middle Coal Measures.
CL = Carboniferous Limestone.
LS = Lydebrook Sandstone.
C_3 = Shineton Shale.
C_2 = Comley Sandstone.
C_1 = Wrekin Quartzite.
U = Uriconian.
B = Basalt.
Cp = Camptonite.

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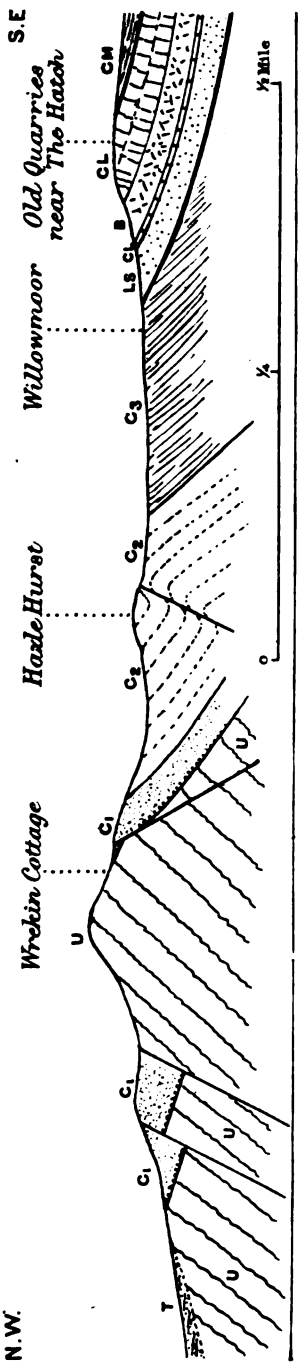

FIG. 2.—*Section across the Wrekin to near the Hatch.*

T = Trias.
CM = Middle Coal Measures.
CL = Carboniferous Limestone.
LS = Lydebrook Sandstone.
C_3 = Shineton Shale.
C_2 = Comley Sandstone.
C_1 = Wrekin Quartzite.
U = Uriconian.
B = Basalt.

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Wrekin Farm the quartzite appears to be absent; but east of Rushton it is seen in an old quarry, dipping south-south-east at about 30°. In the village it rests upon the Rushton Schist. Between Rushton and Charlton Hill the outcrop of the quartzite is not easy to follow; but in Charlton Lane it is clearly exposed, resting upon Uriconian rocks and dipping south-east at 55°. At the southern end of Charlton Hill the dip is S. 10° W. at 45°.

The Comley Sandstone along the south-eastern side of the Wrekin rests upon the quartzite with apparent conformity. West of the Wrekin, between Rushton and Charlton Hill, it is exposed in a stream-course, and again in Charlton Lane, where it succeeds the quartzite.

The Shineton Shale east of the Wrekin overlies the Comley Sandstone, but has not yet been detected to the west of the Wrekin Fault, although it is probable that these beds were entered below Carboniferous rocks at a depth of 189 ft. in a boring at Longwood.

Lower Carboniferous.—In the Wrekin district the Lydebrook Sandstone,[1] so named by Mr. Pocock to suggest its correlation with the Cornbrook and Drybrook Sandstones, has been shown to be of Upper Avonian (D_1) age. It forms the base of the Carboniferous rocks all along their outcrop, from the Wellington reservoir (north of Steeraway) in the north, through Wenlock Wood and Holbrook Coppice, to Lydebrook Dingle.

From the reservoir to Newhouse Farm the Lydebrook Sandstone rests upon the Comley Sandstone; from Newhouse Farm to the southern end of Wenlock Wood it overlies Shineton Shale. From this point possibly as far as the Little Wenlock Fault it is underlain by Valentian rocks, while to the east of the fault, at Holbrook Coppice and in Lydebrook Dingle, it rests on Wenlock Shale and extends as far east as Doseley.

The thin bed of Carboniferous Limestone of D_2 age[2] that overlies the Lydebrook Sandstone has now been mapped all round the outcrop of the sandstone, from the old quarries near the Wellington reservoir, past the Hatch, Wenlock Wood, Little Wenlock, Bragger's Hill and Holbrook Coppice, to Lydebrook Dingle, towards the southern end of which it disappears. The limestone is nodular and of a pale creamy yellow colour.

The basalt of Little Wenlock (*see* Appendix I, p. 140) has been proved by the mapping to rest directly upon this thin limestone band all round its outcrop from the old quarries near the reservoir to Lydebrook Dingle.

From Steeraway in the north to the Hatch and Little Wenlock the basalt is overlain by the main development of the Carboniferous Limestone of the district. This consists of alternations of limestone with beds of sandstone and shale, a good bed of hard white sand-

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 39. *See also* S. Bracewell in 'The Geology of South Shropshire,' *Geol. Assoc.*, 1925, p. 69.

[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 39.

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stone forming the base. The limestones are, in general, of a bluish grey colour, thus contrasting with the pale creamy yellow of the thin limestone below the basalt.

Although this upper limestone is well developed at Little Wenlock, it does not appear to extend to the south-east of the Little Wenlock Fault, and is certainly absent in Lydebrook Dingle.

Coal Measures.—The Middle Coal Measures of the Coalbrookdale Coalfield rest with marked unconformity upon the older rocks. At Steeraway their base is formed by a pebbly hard sandstone perhaps 30 ft. thick. This sandstone can be seen above the upper limestone in Limekiln Wood, at the old quarries north-west of Little Wenlock, and at Huntington.

East of the Little Wenlock Fault the upper limestone appears to be absent. There are no clear sections along the outcrop at Bragger's Hill and the Moors, but in Lydebrook Dingle there is little doubt that the Middle Coal Measures rest directly on the basalt. At the southern end of the dingle, where the basalt disappears, a bed of supposed agglomerate[1] is now considered to be a conglomerate derived in part from the denudation of the basalt. If this view is correct, this peculiar band forms the local basement-bed of the Middle Coal Measures. Still farther to the south-east, at Stoney Hill and Wynne's Coppice, shales and sandstones form the base of the Middle Coal Measures. These rest directly upon the Lydebrook Sandstone. In the large quarries at Horsehay and Doseley, grey sandstone of the Middle Coal Measures overlies the basalt.

In the main part of the coalfield (in Sheet 153) the Middle Coal Measures form two distinct basins beneath the unconformable cover of Upper Measures. The south-eastern or Madeley basin lies between two faults striking north-eastward: the Limestone Fault on the north-west and the Madeley Fault on the south-east. Careful plotting of the trends of the outcrops of the various coals in the Middle Measures at the surface on which the Upper Measures were deposited shows that the Madeley basin is a syncline whose axis runs north-eastward, roughly parallel with the faults that bound it. The syncline is also shown to be pitching north-eastward.

These considerations suggest the possibility that the basin deepens towards the north-east under Shaw Farm and Blithbury, and that all the principal coals of the Middle Measures may be present over a large area in this direction.

Trias.—In Sheet 139 Mr. Pocock finds that between Stone and Stafford, and also south-west of the latter, the ground is all Keuper Marl, except where, along the Trent valley and near Haughton, boulder-clay masks the surface, or where outlying patches of pebble gravel cap the higher ground, as at Willowmore Hill, Berry Ring, and Stafford Castle.

In the area surveyed by Mr. Whitehead a strip of Bunter, succeeded by the Lower Keuper Sandstone, lies between two faults.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 39.

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These faults enter the area, the one at Wooliscroft, a mile west-south-west of Hilderstone, the other 5½ furlongs farther east. The western fault runs with a slightly sinuous course to a point about a mile north-east of Acton Trussell, where it seems to die out in the Lower Keuper Sandstone. The eastern fault dies out, or at least ceases to be traceable, in the Keuper Marl outcrop of Ingestre Park. The Keuper Marl abuts against these faults to the west and east respectively; but where they die out towards the south it succeeds the Lower Keuper Sandstone normally. Exposures in the Keuper Marl close to the faults show, in several places, considerable disturbance of the beds.

The Bunter in this area belongs lithologically to the Pebble Bed subdivision. It consists of rather coarse red sandstones with lenticles of pebbly sandstone and occasional thin beds of marl. About Walton and Brocton the outcrop broadens and becomes continuous with that of Cannock Chase, shingle-beds becoming a more important element of the formation than is the case farther north.

The base of the Lower Keuper Sandstone has been placed at a bed of red marly sandstone or sandy marl, at which, along the greater part of its outcrop, springs of water break out. It is doubtful whether this marly bed should itself be included in the Bunter or in the Keuper. It is in most places too thin for the difference in position between its top and its bottom to be appreciable on a six-inch map; but where the form of the ground requires a distinction to be made, the top of the bed has for convenience been regarded as the top of the Bunter.

This marly bed is succeeded by buff and yellow medium-grained sandstones, an outlier of which caps Beacon Hill, in the township of Hopton and Coton. Above these sandstones comes a bed of marl, 10 to 20 ft. thick, which, persistent about Sandon Bank and Hopton Heath, appears to die out near Tixall Park. The subdivision of the Lower Keuper Sandstone by this bed of marl has proved useful in enabling the relations of that formation to the Keuper Marl to be ascertained. The marl-bed is followed upwards by sandstones that are thick bedded and rather fine in grain. These have been quarried for building-stone near Weston and in Tixall Park. These sandstones and those also below the marl-band appear to become thinner when followed from Hopton Heath towards Tixall, and the upper group becomes interbedded with thin marl-beds. The narrowing of the outcrop of the Lower Keuper Sandstone towards the south-east in this district thus appears to be due to an attenuation of its several portions, rather than to overstep or overlap by the Keuper Marl.

The Keuper Marl contains salt-beds at Weston and Stafford.[1] The salt industry has died out at the former place, but is important at the latter.

[1] Sherlock, R. L., 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xviii (Rock-Salt and Brine), 1921, chap. v.

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Keuper Marl with Skerries, Hazelwell, King's Heath.
[Taken from the Geological Survey memoir on 'The Country around Birmingham,' 1925.]

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Glacial and Post-Glacial.—In the area surveyed by Mr. Whitehead a pebbly red boulder-clay lies upon the high ground about Hilderstone, Hardiwick Heath, and Dayhills, with an outlying patch on Cromer Hill (Sheet 140). Hereabouts the deposit was nowhere found below 550 ft. above O.D. Near Garshall Green (Sheet 140) the boulder-clay, which seems more gravelly, appears to descend in places to 500 ft. In the area examined there is no connecting link between this high-level boulder-clay and other patches that lie in the Trent valley near Aston and Enson, and also to the north and east of Stafford. With the exception of a doubtful patch south-east of Hopton Heath this low-level boulder-clay nowhere ascends as high as 400 ft. above O.D. In it a good exposure is afforded by a brick-pit near Stafford Common, where brownish-purple unbedded clay, up to 8 ft. in thickness and studded with pebbles, rests upon the Keuper Marl. In this clay a boulder of Ennerdale granophyre, about 2 cubic feet in volume, was noted.

The courses of the rivers Sow and Penk are bordered by sands and gravels that in places ascend the sides of the valleys to a height of 300 ft. above O.D. These should probably be regarded in the main as Late-Glacial gravels, such as were found near the junction of the Tame and the Trent.[1] Near Acton Bridge, Rickerscote, and Queensville, in the Penk valley, and below Stafford in the Sow valley, the sands and gravels have the form of a definite terrace, the general level of which is from 10 to 15 ft. above the flood-plain. It is possible, therefore, that the material forming this terrace is a river-deposit of later date than the remainder of the gravels. There appears, however, to be no difference in composition, and the boundary between the terrace-forming gravels and those which ascend to higher levels is in many places very vague. Gravels, also believed to be of Late-Glacial origin, extend continuously down the Trent valley from Stone to Enson, with detached patches near Salt and Weston, beyond which last place the survey has not been carried. A gravel-pit situated near the south-east corner of Sandon Park exposes about 20 ft. of these gravels. They are coarse and rudely bedded and contain many far-travelled pebbles and boulders, amongst which there is much Coal Measure material as well as igneous rocks. In the Trent valley there are, in addition to these Late-Glacial gravels, others lying at a lower level and forming a definite terrace. Where the two occur in juxtaposition there is usually a distinct feature or change in slope at the junction. The greater part of this terrace lies less than 10 ft. above the flood-plain, whereas the Late-Glacial gravels rise to over 20 ft. above that level.

T. C. CANTRILL.

REVISION IN SOUTH WALES

A revision of the memoir on the Abergavenny district (Sheet 232), which has been out of print for some years, and of some of the

1 'Geology of the Country around Lichfield' (*Mem. Geol. Surv.*), 1919, p. 190.

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six-inch maps of that area has been in progress during the past season (1925). This district includes about 70 square miles of the north-eastern corner of the South Wales Coalfield and most of the northern half of the Silurian inlier of Usk. The remainder is made up of the intervening Old Red Sandstone, Carboniferous Limestone, and Millstone Grit. In the Silurian area a horizon corresponding with that of the Aymestry Limestone has been laid down on the one-inch map. The zones of the Avonian sequence have been applied to the lithological sub-divisions of the Carboniferous Limestone established during the survey of the area on the six-inch scale. The north-eastward transgression of the Limestone by the Millstone Grit has also received attention. These and other matters, however, are subservient to the needs of the coalfield itself, in which the progress of mining has made available a mass of information that forms the main subject of the revision. The published six-inch maps of the area are also being brought up to date.

T. ROBERTSON.

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3. YORKSHIRE DISTRICT

Headquarters: York

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G. V. Wilson, B.Sc., Senior Geologist.
D. A. Wray, M.Sc.
J. V. Stephens, B.Sc., B.Eng.
Wilfrid Edwards, B.A.
} Geologists.

DURING 1925 the resurvey of the Huddersfield Sheet (77) of the one-inch map has been completed, and the preparation of six-inch quarter-sheets for publication has been begun. This work has occupied the whole of the staff with the exception of Mr. Wilson, who has continued his investigation of the Concealed Coalfield of Yorkshire and Nottinghamshire, and also mapped a small area in Sheet 86 (Glossop) of the one-inch map.

In the Huddersfield area the beds mapped extend from the Elland Flags to the Warren House or Barnsley Coal; Mr. Wray took the district lying east of Huddersfield and south of the Calder, including the villages of Kirkheaton, Lepton, Hopton, Thornhill, Whitley, Kirkburton, Flockton and Emley; Mr. Bromehead the Calder valley eastwards of Bradley and some of the high ground to the north, including Mirfield, Hartshead, Liversedge, the southern part of Cleckheaton, Heckmondwike, Ravensthorpe, Dewsbury and Chickenley Heath. To Mr. Edwards was allotted a narrow strip extending eastwards from Wyke to Cleckheaton, Hunsworth, Gomersal and Birstall and also the eastern margin of the area from Batley on the south through Morley and Gildersome to Bramley and Armley; Mr. Stephens mapped the greater part of Bradford, Farsley, Pudsey, Tong, Wibsey and Drighlington. The following account has been compiled from material supplied by each member for the area he surveyed.

Lower Coal Measures.—The lowest measures mapped during the year belong to the Elland Flagstones: a large part of Bradford is built on the outcrops of the several beds into which the group is here split up; the district is much affected by faults, many of which are visible in the cutting on the City Road branch of the Great Northern Railway. Farther south, where covered by newer beds, the Elland Flags are of some value as a source of underground water supply. In the boring at Calder Colliery, Ravensthorpe[1], the flags are again divided by shale to form a number of small beds, as is the case in the escarpment on the right bank of the Colne and its tributary from Colne Bridge to Fenay Bridge. South of the latter locality shafts have been sunk during the last few years through a considerable thickness of measures to the Halifax Hard Bed and

[1] 'Sections of Strata of the Coal Measures of Yorkshire,' *Mid. Inst. Mining Eng.*, 1914, pp. 29–31.

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the Soft Bed Coals. These have been found to maintain their usual characters and thicknesses exhibited in the country to the west of Huddersfield, where they were long ago mined near to the outcrop. Both the coals and the fireclays are being mined, the latter for the manufacture of glazed stone-ware locally.

It has long been known that the Better Bed Coal is a valuable seam over only a comparatively small area which is now nearing the worked-out stage. In the north the fireclay beneath it is worked around Farnley and Wortley, the thickness varying from about 1 ft. 10 in. to 4 ft. 6 in.; but the coal seldom exceeds 1 ft. A few small outliers of this coal have been mapped between Westgate Hill and Pudsey. Along the Thornton branch of the Great Northern Railway the Better Bed is exposed at Great Horton Road, where the coal is thrown down between two faults, and also at the east end of Horton Park station, where it is again faulted in. In the central area the coal has been worked almost as far east as Dewsbury, but is becoming attenuated, so that no further development is likely; a few of the more recently proved thicknesses are as follows: Stanley Colliery, Liversedge, 1 ft. 2 in.; Mirfield Moor 1 ft. 4 in. in shaft, 1 ft. 5 in. in 1924; Dark Lane, Ravensthorpe, 1 ft.; Conyers Colliery 1 ft. 3 in.; Ravenslodge 1 ft. 0½ in.; Ingham's Pit, Thornhill, 10 in.; Shaw Cross 1 ft. 3½ in.; Batley West End 10 in.; at Combs Pit there are two bands 1 ft. and 10 in. thick separated by 7 in. of 'muck'. In the south it is as much as 1 ft. 6 in. at Highburton, but dies out immediately to the south of Kirkburton. In this district it rests directly on the uppermost bed of the Elland Flagstones.

The measures between the Better Bed and the Black Bed here consist of soft mudstone about 90 ft. thick and are being extensively quarried for bricks at Cowmes near Fenay Bridge and were worked for the same purpose in the past to the south of Kirkheaton. In the north the Thick Stone intervenes in this position; the measures from that bed up to the Crow Coal are exposed in two brickpits at West Bowling and also in the railway cutting to the east of St. Dunstan's Junction.

The Black Bed has been got over a large part of the area and is still the principal seam at a number of pits. In the brickpits just mentioned it is about 2 ft. 4 in. thick, and the overlying ironstones are also seen.

The coal maintains a fairly uniform thickness over the greater part of the area: it is 2 ft. 3 in. at Stanley, where it is 125 ft. above the Better Bed, but 2 ft. 6¾ in. at Strawberry Bank and 2 ft. 6 in at Gregory Spring, Hopton and at Combs Pit, Thornhill, the height above the Better Bed remaining practically the same. At Heaton Hall, Kirkheaton, it is still as much as 2 ft. 1 in. but is divided by a dirt parting. Like the Better Bed, it deteriorates southwards and dies out to the south of Kirkburton. A washout trending nearly west and east has been traced from Upper Hopton to Thornhill.

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Between the Black Bed and the Clifton or Oakenshaw Rock the Crow Coal can usually be identified in shaft-sections, but its outcrop can seldom be traced; in the southern approach-cutting to the tunnel between Low Moor and West Bowling an excellent section is exposed from the Crow Coal to the base of the Clifton Rock, showing the Twenty-two and Thirty-Two Yard Coals. A plant-bed exists here immediately below the Crow Coal. In the south the Grenoside Rock immediately overlies the Black Bed: at Kirkburton and Lepton it is a fine-grained flaggy sandstone, but it appears to be thinning away at Kirkheaton and is unrepresented further north; the Crow Coal is persistent and rests directly on the Grenoside Rock; some flaggy beds above the coal may be the attenuated representative of the Penistone Flags, which are strongly developed to the south of the present area.

The Clifton or Oakenshaw Rock has been much worked around Battyeford, but most of the quarries are abandoned.

The complicated series of coals between the Clifton Rock and the Blocking Coal were investigated fully by Green[1], and the results of the re-survey, as far as they have been studied as yet, confirm his conclusions. In the north the widening of the Huddersfield Road at Hill Top, Low Moor, has exposed, between two faults, the Shertcliffe Bed Coal resting on the top of the Clifton rock; the coal is here 2 ft. 7 in. thick, the lower part being a stone coal. Along the southern side of Tong Street the Shertcliffe Bed and the Little Coal are visible in the Victoria Brick Works, Dudley Hill, and in the two railway cuttings to the east. The measures between the Shertcliffe Coal and the Blocking Bed cover the area between Westgate Hill and Tong, and also that around Toftshaw and High Royds Beck; they contain as many as seven thin coal seams of no economic importance. At Farnley the Churwell Thick and Thin coals, or Low and Top Beeston coals of the area to the south and west come together to form the Beeston Bed; no sections are now visible. In the faulted inlier of Lower Coal Measures at Liversedge the (Upper) Lousey Coal is about 110 ft. above the Shertcliffe Bed, with intermediate coals at 17 and 37 ft. At Battyeford they are about 75 ft. apart and intermediate beds have not been detected. In the south the name Whinmoor Coal is given to the lowest of this group of seams and Shertcliffe to one between it and the Lousey Bed; they show considerable variations when traced across the outcrop. Thus, the Whinmoor, which consists of a single seam 20 in. thick around Lepton, splits into two and possibly three unimportant seams when followed southwards. It is hoped to effect a correlation of these several seams in the forthcoming memoir.

An approximate thickness for the Lower Coal Measures of the district is given by the boring at Calder Colliery mentioned above: the Millstone Grit was reached at a depth from the surface

[1] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 175–227.

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of 1,537 ft. A fault with estimated throw of 90 ft. cut out the Halifax Hard and Soft Bed Coals, and the total from the Blocking Bed to the Rough Rock should be approximately 1,500 ft. In the northern part of the area the thickness decreases to about 1,210 ft.

Middle Coal Measures.—The Blocking Coal maintains a very uniform character with a thickness round about 2 ft. throughout the area and has been extensively mined. The succeeding coals, the Wheatley Lime or Three-quarters, the Middleton Eleven Yards, the Cromwell, Yard, Middleton Main or New Hards and the Green Lane or Middleton Little have all been largely worked at shallow depths near the outcrops. The Lime Coal is exposed in the Taylor Hall Brickpits north of Mirfield and the Green Lane is being worked on a small scale in the south bank of the Calder opposite Ravensthorpe and farther south. A hard ferruginous band crowded with *Carbonicola* immediately overlies this coal in the Whitley district. A prominent bed of sandstone forming high ground at Emley Moor overlies it in the southern part of the area, but appears to dwindle away in a northerly direction.

The mapping of the Brown Metal or Old Hards has proved of great interest. As mentioned in last year's Summary it is affected by an important washout, the infilling of which is the Birstall Rock. Near the eponymous locality the rock is as much as 80 ft. thick and has been largely quarried. The washout is well seen in the valley of the Batley Beck, where evidence of local movement before the deposition of the Birstall Rock has been obtained. The margin of the washout was found in the old workings at White Lee, as recorded by Green (*op. cit.*, pp. 291–293) who figures two instances of the oncoming of sandstone in the coal; at one spot he found a total of 9 ft. 1½ in. of coal and was informed that at another as much as 10 ft. 4 in. occurred; the normal thickness is from 4 ft. to 4 ft. 6 in. In the shaft at the present White Lee Colliery the section given us amounted to 6 ft. in all, including several partings of dirt, etc. The outlier at Robert Town lies well to the west of the washout; the section there is coal 2 ft. 8 in., fireclay 3 ft. 6 in. to 4 ft., coal 1 ft. 3 in., a clear indication of the splitting of the seam into two. The 'Third Brown Metal' is here 1 ft. 7 in. thick 15 ft. below the base of the main seam. To the south-east these coals become the first, second and third Old Hards seams and are variously affected by the washout. The Birstall Rock occupies the area of Crow Nest Park, Dewsbury, and at certain points is known to rest directly on, or cut out a coal, though it is seldom possible to say which of the three seams this is. Daw Green and much of West Town were built over at the time of the original survey, but we were fortunate to see a good section during the widening of the road to Mirfield; the coal was 2 ft. 6 in. thick and the sandstone came on immediately above; the outcrop lies about one furlong south of that shown on the old six-inch map. It seems probable that the position of the Spen valley, below Heckmond-

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wike, has been determined by the western margin of the Birstall Rock. In the isolated hill between Savile Town and Thornhill Lees the three Old Hards Coals are all present: a sandstone immediately above the lowest is marked 'Birstall Rock' by Green, but there is shale between it and the second coal, which may at times be seen in the graveyard of Holy Innocents Church; a second sandstone intervenes between the second and first coals, but is separated from both by shale. Evidence of a washout is, however, obtained in the first or highest coal: on the south-west side of the hill, towards Thornhill Station there is at least 20 ft. of shale between the coal and the base of the sandstone; but on the other side the latter descends and, in the cutting on the Midland Railway, is seen to cut out the coal. The sandstone has been quarried to a depth of 15 ft., and its lower part contains pebbles of shale, coal and ironstone nodules. As far south as Flockton, the Old Hards or, as it is here beginning to be called, the Parkgate Coal is overlain by a prominent, massive sandstone, giving rise to several features. This sandstone is evidently the continuation of the Birstall Rock, but it dies out very suddenly to the south of Flockton; the coal is sometimes washed out by it, notably along the southern margin of the rock, which has been traced east and west for upwards of two miles through Flockton Green. The eastern margin of the Birstall Rock appears to lie between Drighlington and Cockersdale, through Howden Clough to Lower Soothill and thence between Shaw Cross and Savile Collieries.

The next group of coals contains seams known as the Adwalton Black Bed and Stone Coal in the north, and as the Flockton Thin and Thick in the south, where they are usually separated by a flaggy sandstone known as the Emley Rock. This is apparently absent at the outcrop between Thornhill and Thornhill Lees, but is found again between White Lee and Heckmondwike and to the north. Both coals are practically worked out, the Stone Coal especially having been largely got by bell pits. It is well known as the most important lenticle of cannel in the coalfield; this character is maintained as far north as Briestfield, and small patches of cannel are found at Flockton. Above the Stone Coal a *Carbonicola* band is always present; south of the Calder this band becomes the Tankersley Ironstone and has been seen in several sections around Flockton. To the north and east of Emley its outcrop is largely marked out by a series of overgrown shale mounds, the ironstone apparently having been worked in shallow bell pits many years ago. No records of these workings could be found, and, judging from their completely overgrown nature, they must be very old. A short distance above this ironstone band comes a remarkably persistent seam, the Joan Coal; it is usually too thin to repay exploitation, though it has evidently been tried on a small scale at several places on the outcrop; it was worked in Dewsbury and at Pildacre, where it attained a thickness of 2 ft.

The Thornhill or Morley Rock is perhaps the most prominent

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sandstone in the Middle Coal Measures; the escarpments from Hanging Heaton through Dewsbury Bank to Healey and south of the Calder near Thornhill dominate the landscape over a large area, and the wide plateaux to the east and south of these respective scarps are also conspicuous. The rock has been largely quarried at Morley, where it exceeds 100 ft. in total thickness with 50 to 60 ft. of good stone; also at Dewsbury Bank, where it may reach 100 ft., and near Thornhill. Here the cutting on the recently constructed Midland Railway reveals a fine section; in some beds ironstone nodules are abundant, but they appear to be pebbles derived from older beds, rather than indigenous parts of the rock. At Middlestown the rock is strongly developed as a rather fine-grained flaggy sandstone some 60 ft. thick, but south of the Coxley valley the thickness rapidly lessens and shale partings intervene. Immediately east of Emley it probably does not exceed 20 ft. in thickness, though it still gives rise to prominent features. West of Midgley and south of New Hall Wood it apparently dies out southwards.

East of Batley the (Top) Haigh Moor Coal is some 80 to 100 ft. above the Thornhill Rock, and its thickness is just over 3 ft.; it has been worked out. A small area of Warren House Coal was mapped in this part of the district; an old boring gives the section of the seam as 3 ft. of hard coal resting on 1 ft. 1 in. of soft coal. South of Chickenley Heath the Low Haigh Moor becomes mappable; at Dewsbury Lane Colliery, Ossett, it is 2 ft. 5 in. thick with a 5-in. dirt parting; the Top seam is 30 ft. above it and contains 2 ft. 10 in. of coal with two dirt partings; both coals have been worked at outcrop by a number of day-holes. The Horbury Rock comes on to the west of Ossett on the eastern margin of the area surveyed. South of the Calder the Low seam was worked many years ago in a small faulted inlier east of Thornhill. South of here, these two seams usually go by the names of the Netherton Thin and Netherton Thick coals: they are usually about 30 ft. apart and have both been worked, though they appear to be of inferior quality. A pair of faults running in a south-west to north-east direction from Emley past New Hall Wood towards Horbury let down a trough of higher Middle Coal Measures between them.

Structure.—The structure of the district is as described by Green and indicated on the original six-inch and one-inch maps (87 N.W., 88 N.E.). Mine plans have, however, enabled us to insert a few additional faults and to make certain minor corrections. For instance, the fault which bounds the triangular inlier of Lower Coal Measures at Liversedge on the south-west was shown as splitting into two branches near Crossley Hospital and continuing on either side of Mirfield Church to the Calder. The eastern branch, however, dies out in a short distance near Wellhouse, but the western reaches the river at Shepley Bridge. The outcrop of the Blocking Bed between that point and Knowl was omitted on the

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old six-inch map (Sheet 247), but inserted in approximately the right position on the one-inch map. The almost parallel faults to the east are much as shown by Green; the Dark Lane Colliery, therefore, lies in a narrow fault trough, the Better Bed workings being reached on either side of the shaft from the Black Bed.

Between White Lee and the Spen valley from Cleckheaton to Heckmondwike the structure is complicated and confusing. Green inserted a fault in the valley from Littletown to near Cater Mill, of which he writes:—'the conjectural fault at Mill Bridge has not been seen or proved in any part of its line, but some such fault seems to be necessary to account for the depth of the Blocking Coal (84 yds.) at the shaft near Flush Mill, for the same coal is only a few yards deep in the valley at Mill Bridge' (*op. cit.*, p. 658). The Black Bed has now been mined over the whole of this area and no such fault exists. It is clear that some of the seams in this district have been wrongly named both at the outcrop and in the records of borings, but the details are too complicated to be given here.

Glacial.—Boulder-clay, though thin, covers a wide area in the north, the Airedale ice having advanced as far as a line through Low Moor, Tong Street and Pudsey; isolated patches are found as far from the Aire as Gildersome. The clay contains pebbles and boulders of local Coal Measures rocks, Millstone Grits and Carboniferous Limestone. Striae were observed on the surface of the sandstone in the railway triangle at Quarry Gap, Laisterdyke; their bearing was south 72° east. The boulder-clay along the west side of the railway between Dudley Hill and Laisterdyke is thicker than the average and has at some time been worked for brickmaking just north of Laisterdyke.

In working the Black Bed Coal at Glenfield Colliery, Odsal, at a depth of 38 ft. a drift-filled channel was discovered trending south-west. The coal had been eroded, but part of the seat-earth remained; a 40-yd. heading failed to prove the width of the channel.

Three channels which in turn received the overflow from the water penned up in the Bradford basin by the ice can be traced. The highest, starting at 690 ft. above O.D. at Close Top Farm,[1] runs by Wibsey Bank Foot and the present Dean Beck valley into the Spen valley. The second channel begins close to the first at Rooley Hall (655 ft.),[2] and after a meandering course runs southwards past Bierley Hall to Spen valley, the latter part of its course being now occupied by Hollowfield Beck. Fluvio-glacial gravels deposited partly by the melt-waters of the ice which came over into the Calder basin at Low Moor and partly by these overflows have been mapped at Low Moor and in the upper part of the Spen valley. The third overflow channel at Quarry Gap, Laisterdyke, has an intake level of about 550 ft. above O.D.

[1] Jowett, A., and H. B. Muff, 'Glaciation of the Bradford and Keighley District', *Proc. Yorks. Geol. and Polytech. Soc.*, vol. xv, 1903-1905, p. 224.

[2] *Ibid.*, p. 229.

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and leads by way of the Tyersall Beck valley into that of the Pudsey Beck. Small patches of current-bedded water-worn gravel form a discontinuous terrace along the sides of Tyersall Beck and Pudsey Beck; in the former they are 15 to 20 ft. above the present stream level.

The gravel with abundant foreign stones, mostly of Lake District origin, that floors the Calder valley has been seen in excavations at Dewsbury and appears above the alluvium on the south side of the river west of Horbury.

Glossop Sheet

The revision of the ground covered by this map (New Series Sheet 86) was begun by Mr. Wilson in the intervals of his work on the Concealed Coalfield. The ground examined contains a sequence of rocks extending from low down in the Kinderscout Grit to the Halifax Hard Bed Coal.

Millstone Grit.—The lowest beds are exposed at the western end of Woodhead Tunnel. They consist of alternations of coarse grits and sandy shale and, according to the geological section of the rocks passed through in the air-shafts of the tunnel, are overlaid by black shales with goniatites and *Pterinopecten*. The shales are not exposed on the line of the tunnel, but are probably represented by material occurring on the refuse heap at No. 2 Shaft, which contains *Reticuloceras reticulatum*, mut. *a* Bisat. The succeeding 300 ft. of strata consist of alternating barren sandy shales and sandstones, which are overlaid by bluish shales with *Pterinopecten* and *R. reticulatum*, mut. β. This bed is well exposed in Withens Brook, about a mile north of Woodhead Station.

The sandstone which was taken as the base of the Third Grit Series occurs 60 ft. above the last-mentioned marine bed. It is about 70 ft. thick, current-bedded and was worked in the old quarries on Greystone Edge, where it forms a bold escarpment. The next 150 ft. or so of strata consist of thin-bedded, alternating bands of flaggy sandstones and sandy shales, which are seen in Salters Brook and Windleden (the valley containing two reservoirs south of the tunnel). Near Dunford Bridge the upper members of this group contain a good deal of flaggy sandstone, which has been quarried on an extensive scale at Lower Windleden. The quarry also exhibits an excellent section of an overlying marine bed. The same horizon is thought to have been noticed in Long Grain, half a mile east of Dunford Bridge; in Cabin Clough, a tributary of Loftshaw Brook, 2 miles to the south, and in Dearden Clough, the valley which runs parallel with and on the north side of the tunnel at its eastern end; but until the goniatites have been determined the correlation is uncertain. At this locality the marine bed is seen to lie 50 or 60 ft. below the sandstone which underlies the Upper Meltham Coal, here described as the Ramsden Edge Rock. This rock occupies most of the gently sloping plateau which

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stretches southwards and westwards from Cook's Study, and forms a magnificent feature at the head of Ramsden Clough. It is overlaid by about 70 ft. of fissile blue shales, which have yielded two marine bands. The lower of these contains *Gastrioceras cancellatum* Bisat and is equivalent to the Holcombe Brook Marine Band. The shales are succeeded by the Rough Rock Flags, which are exposed in numerous quarries between Cook's Study and the bottom of Harden Clough. A striking peculiarity of these beds is that they are much folded and often vertical, although as far as can be ascertained the underlying shales are practically undisturbed.

The Rough Rock Flags are followed by a few feet of sandy shale with a dirty coal above. The Rough Rock rests directly on the coal, which in some instances it has partly removed. Excellent sections of these measures are to be seen in Hade Edge and Harden Quarries between Holmfirth and Dunford Bridge.

Coal Measures.—An exposure of the marine bed which occurs above the Rough Rock was noted about 200 yds. up a small stream on the east side of the road from Dunford Bridge to Holmfirth, and a third of a mile south-east of Harden. Some 50 ft. higher in the sequence a fine-grained whitish sandstone, which forms the high ground of Tinker Hill, may be regarded as the equivalent of the Crawshaw Sandstone.

The old workings in the Soft and Hard Bed coals show the position of the outcrops of three seams in the neighbourhood of Law, where the floor of the Middle Bed is being worked for ganister. This bed and the overlying Hard Bed with its marine roof are well exposed in the clay pit of the Hepworth Iron Company at Crow Edge.

Miscellaneous.—Mr. Wilson describes some of the results of his work on the Concealed Coalfield in Appendix V. In addition to their normal work, the results of which are outlined above, the staff have examined several sections exposed in new railway works and road cuttings. An examination of samples from the new oil boring at Hardstoft confirms the section drawn up for the original hole, which is remarkable in that no sandstone or grit of any consequence occurs between the Rough Rock and the Carboniferous Limestone. Mr. Stephens spent a considerable time in a joint survey with an agriculturist of the drift deposits between Stockton-on-the-Forest and Stamford Bridge (six-inch Sheet 158 S.W.). The part of the 'York Moraine' near Gate Helmsley was found to consist almost entirely of boulder-clay, with gravel beds on the flanks, but the whole is covered by a thin layer of sand; the clay reaches the surface in a great number of small irregular 'windows' which were mapped out in detail: the resulting map is too intricate for reduction to the one-inch scale. A part of Mr. Edwards' time was occupied in preparing the memoir on the Wells and Springs of Dorset.

Some thirty enquiries, mainly concerning water-supply, were

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dealt with. Our thanks are due to various water-boring firms for records of boreholes and also to numerous colliery companies and their agents for access to plans and details of sections, without which but little real revision of the maps in the area surveyed would have been possible.

Concealed Coalfield

Mr. Wilson has visited a number of borings in the concealed coalfield of Yorkshire and Nottinghamshire, but in most cases sanction has not yet been obtained to publish the results in full. An interesting boring is in progress at Sutton near Retford. It has now passed below the position of the Top Hard Coal, and the following details of the section above that coal are now given. The base of the Bunter occurred at a depth of 597 ft. 9 in.; Upper Permian Marls extended to 632 ft. 8 in.; the Upper Magnesian Limestone to 677 ft.; the Middle Marls to 838 ft.; the Lower Magnesian Limestone to 1,083 ft. 11 in.; the Marl Slates to 1,092 ft. 7 in. and the Basal Breccia to 1,096 ft. 10 in. at which depth Coal Measures were entered. The Basal Breccia was much finer grained than in the ground to the south, and consisted mainly of grey sandstone with layers of gritty materials.

The bore has proved 1,586 ft. of Coal Measures above the Top Hard Coal. The higher beds yielded *Anthracomya phillipsi*, and a coal 1 ft. 10 in. thick at 1,403 ft. The Top Marine Bed occurred at a depth of 1,659 ft. 9 in.; the Mansfield Marine Bed at 2,099 ft. 6 in.; marine shells at about 2,160 ft. and the Top Hard Coal, of which an excellent core was obtained, at 2,682 ft. The marine bed at 2,160 ft. is regarded as being the same as that which has been found about the same distance below the Mansfield Marine Bed at Maltby, Haughton, and Ollerton. No signs of a coal with cannel nor of marine fossils or *Lingula* in the roof were encountered at the position of the Abdy Coal. Similar conditions were noted at Haughton; it would, therefore, appear that the Abdy is missing in this part of the area, though it occurs at Harworth to the north and Ollerton to the south.

The measures for about 300 ft. above the Top Hard Coal yield numerous plant remains, and the sandy shales only a short distance above the coal are beautifully current-bedded.

The bore is of great interest since it proves the existence of an excellent Top Hard Seam in this part of the area. It also shows that the absence of that coal in the previous boring at Hayton Smeathe (just over two miles to the E.S.E.) was most likely due to faulting, and not to its being removed by an easterly extension of the Manton 'Wash'. Also since the thickness of measures intervening between the Mansfield Marine Bed and the Top Hard Coal is about 577 ft., it is hardly possible that the seam at 3,073 ft. (833 ft. below the Mansfield Marine Bed) at Hayton Smeathe is the Top Hard.

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In the light of the evidence supplied by this boring it is possible to make an attempt at a new interpretation of the journal of Haxey bore, on the assumption that the identification of the Barnsley Coal at Haxey is correct.

As already stated, 1,586 ft. of Coal Measures occur above the Top Hard Coal at Sutton. At Haxey the thickness is 1,405 ft. or 181 ft. less than at Sutton. The so-called Shafton at Haxey may be regarded as the same as the seam 1 ft. 10 in. thick at 1,400 ft. at Sutton. Since the Shafton Coal in the west underlies the Top Marine Bed, whereas the Sutton coal occurs some 250 ft. above the Top Marine Bed, it is evident that the two are not on the same horizon,

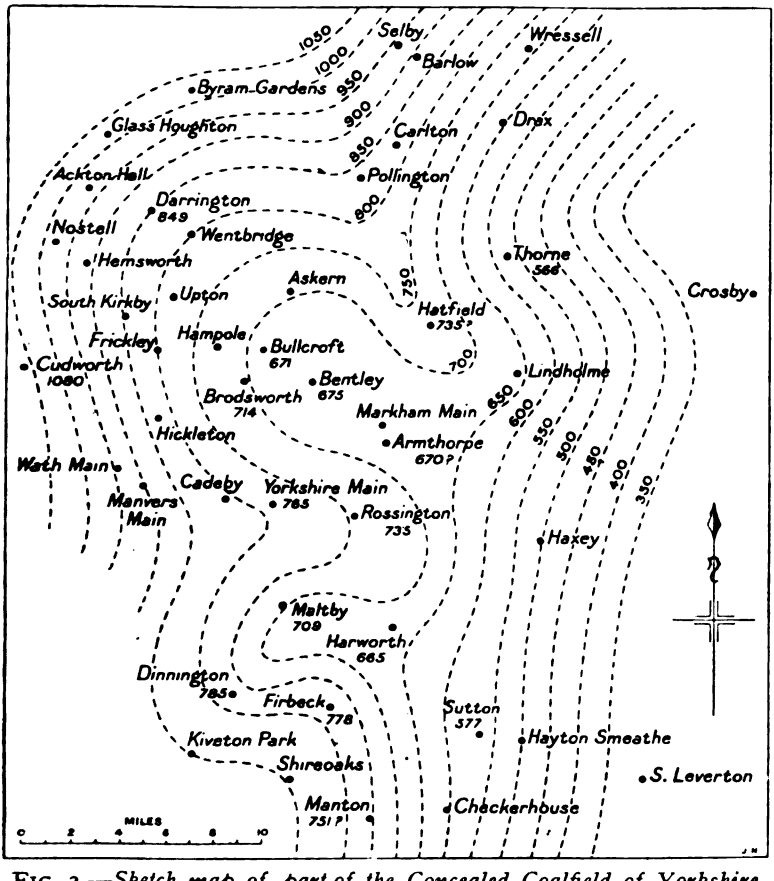

FIG. 3.—*Sketch map of part of the Concealed Coalfield of Yorkshire and Nottinghamshire showing isopachytes between the Mansfield Marine Bed and the Barnsley Coal.*

and the latter must be regarded as equivalent to one of the seams which occur above the Ackworth Rock in many of the shaft sections to the west. The Bagshaw Coal of Haxey may be regarded as the one below the Top Marine Bed, and so about the position of the Shafton, and the Wathwood as the seam below the Mansfield Marine

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Bed. No correlations can be made between this position and the Barnsley, though the Abdy is about in its true place in the sequence. The Barnsley Hard may be regarded as the Dunsil.

In the 2nd edition of the Memoir on the Concealed Coalfield of Yorkshire and Nottinghamshire (p. 34) a map is given which shows by isopachytes (lines indicating equal thickness) the variations in the thickness of the measures intervening between the Mansfield Marine Bed and the Top Hard or Barnsley Coal. Since its preparation a considerable amount of further information has been gathered, and it is now possible to publish a new map (Fig. 3). During the course of last summer a visit was paid to a brick pit near Cudworth Station with Mr. W. H. Wilcockson of Sheffield University. A marine bed is there exposed which has all the characteristics of the Mansfield Marine Bed, including the basal cank, coal and fireclay below. It, however, overlies the Oaks Rock instead of being below it as has been supposed to be the case in the Concealed Coalfield. Fortunately the base of the Oaks Rock is now well exposed in a new railway cutting about 6 miles to the north. At that locality there are no signs of a marine bed below the Oaks Rock although a coal, presumably the Swinton Pottery Seam, is exposed. It seems exceedingly probable, therefore, that the bed exposed at Cudworth is the Mansfield Marine Bed. According to measurements taken from the levels in the workings of the Barnsley Coal below, the distance between the two horizons is 1,080 ft.[1]

From an examination of the map it will be noticed that a diminution of over 500 ft. in thickness takes place as the measures between the Mansfield Marine Bed and the Barnsley Coal are traced eastwards from Cudworth to Thorne. Further to the south the rate of decrease is about 350 ft. in 8 miles. This may be considered as normal, and the variations from it, between Yorkshire Main and Thorne, suggest that movements along the line of the Don faults were taking place during the period of deposition of these measures.

If this average rate of thinning should continue eastwards towards and beyond the River Trent, it would mean that in this eastern area the Mansfield Marine Bed must lie only a short distance above the Barnsley Coal. One is tempted to ask if by any chance it even cuts out the coal altogether, or whether on the other hand it dies out itself. If by any chance the intervening measures should be found to thicken again in the east, it may be surmised that the sedimentation came from a different source from that in the west. In such a case it is exceedingly unlikely that it would be possible to correlate the coal seams in the two areas accurately.

This thinning of the measures to the east is of prime importance in connection with the eastward development of the Concealed Coalfield, since it has caused the Barnsley or Top Hard Coal to lie much nearer the surface than it otherwise would have done, and in some cases has even brought it within present limits of working depth.

C. N. BROMEHEAD.

[1] Kendall, Prof. P. F., and H. E. Wroot, 'Geology of Yorkshire', 1924, p. 913.

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4. LANCASHIRE DISTRICT

Headquarters: Manchester

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IN Lancashire the revision of the Manchester area, Sheet 85, has been continued. The district is heavily cloaked with drift deposits and very poorly exposed. Under these conditions the information afforded by mining operations and the sinking of wells becomes of special value, and a great proportion of the time of the geologists has been occupied in collecting such records. Very little progress would be possible without the willing co-operation of the mining officers and municipal engineers, which is here gratefully acknowledged. Thanks are due also to the well known boring firms of the district, who have generously given access to their boring operations and supplied many indispensable bore-journals.

Manchester lies at the north-eastern corner of the Cheshire basin with the uplands of the Rossendale anticline to the north and those of the Southern Pennines to the east. These uplands are formed in the main of Millstone Grit and the dip of the beds towards the centre of the basin brings on successively the Lower, Middle and Upper Coal Measures, and finally the unconformable Permo-Triassic beds. On this general structure is superimposed a complicated and powerful system of faulting, with a general north-westerly trend, and both pre-Triassic and post-Triassic in age. Sheets 89 S.E. and 88 S.W. of the Old Series give a fair general idea of the geology of the area, but the accumulation of information and better correlation have necessitated a number of important alterations, some of which are indicated below.

Mr. Lloyd has continued his field work in the south-eastern part of Sheet 85 and adjoining parts of Sheets 86 and 98. Attention has been devoted chiefly to the Millstone Grits of the Mossley valley, and the Middle Coal Measures of the Hyde, Denton and Bredbury districts. Little detailed information is available regarding the Lower Coal Measures on account of the relative absence of mining and lack of exposures. As in the case of the Oldham-Ashton area, ready help and willingly given information has been forthcoming from the colliery officials. Acknowledgments in this respect are due to Mr. Davis, managing director, and Mr. W. Graham, of Denton Colliery; to Mr. Hamilton, managing director, and Mr. Backhouse, secretary, of Bredbury Colliery; and to the Ashton Moss Colliery Co.

Mr. Tonks has been engaged upon the obscure and ill-known area extending north from Manchester to Heywood. A great deal of underground information and records of boring operations have been collected; and for these records, invaluable in such ground,

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we are indebted to Messrs. Platt Bros., and to Mr. Richford, manager of their Moston Colliery; to the Chamber Colliery Co.; to Messrs. Thos. Matthews, Ltd., of Pendleton; Mr. John Thom, of Patricroft; and Mr. W. Mansfield of Liverpool.

Dr. Sherlock revised the district between Bolton and Bury and received much assistance from the Clipton and Kearsley Coal Co., the Bryn Hall Colliery Co., Ltd., the Ladyshore Colliery Co., Ltd., and from Mr. T. A. Oakes, agent to Lord Derby.

Mr. Jones was employed to the west of Bolton in a region where very little mining is carried on at the present day.

Much valuable information regarding this area has been supplied by Mr. E. Le Morgan, Borough Surveyor of Bolton, and by his assistants; by Mr. E. H. Rosbottom, managing director of Victoria Colliery; and by Mr. J. Lomax, F.G.S., of the Lancashire and Cheshire Coal Research Association. Messrs. Wm. Matthews and Co., Ltd. provided a number of valuable boring records, as did also Messrs. Thos. Matthews, Ltd. and Mr. J. Thom.

Millstone Grit Series.—Outcrops of Millstone Grit are almost entirely confined to a belt along the eastern margin of Sheet 85, where they have been investigated by Mr. Lloyd. The Mossley valley from Grasscroft to Stalybridge is occupied by beds of this age ranging down to the Kinderscout Grit series. The latter was formerly mapped as one bed of grit, but it is now found to admit of subdivision into Upper and Lower (or main) Kinderscout Grit. The two are separated by 120–150 ft. of sandy shales with lenticular grit bands. The shales overlying the Upper Kinderscout Grit are exposed in the railway cutting west of Grasscroft station, where they are found to contain, near the base, the marine horizon of *R. reticulatum*, late mut. *a* Bisat.

The Upper Kinderscout Grit is variously textured and includes beds of massive coarse grit, the full thickness being about 150 ft. A thin coal seam occurs near the top.[1] The main bed of Kinderscout Grit is largely conglomeratic and attains a thickness of at least 350 ft.

The anticlinal fault, which was shown to have no tectonic significance on the Lancashire—Yorkshire border to the north[2] assumes considerable importance in this area. Its N.–S. course (coincident with the axial trend of the Pennine anticline) can be traced along the eastern slopes of the Mossley valley; the Kinderscout Grit of the high moorlands being thrown into the valley bottom near Mossley, while further south, in the Matley district, the grit is well below the surface on the west side of the anticlinal fault, which passes between the Kinderscout escarpment of Harrop Edge and the shales with *R. reticulatum*, mut. *β* Bisat of Westwood Clough.

The characteristic variability of the Holcombe Brook Series[3]

[1] *Cf.* 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 52, Fig. 2.
[2] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 46.
[3] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 49.

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is revealed by the following two sections taken from the north and south of the area dealt with :—

Leadbeaters Brick Works Quarry, Thornley (north)

	Ft.	in.
Dark Shale		
Holcombe Brook Coal (poor)	3	0
Fireclay	1	8
Lenticular brown sandstone	0 to 1	10
Fireclay	8	0
Hard fine siliceous flagstone	8	0
Coal	1	10
Fireclay	3	0
Shale	10 ft. to 12	0
Ganister	3	6
Grey mudstone (with bivalves)		

Acre Clough, Stalybridge (south)

Dark shale with *G. cancellatum*
Thin coal
Fireclay
About 30 ft. fine brown irregularly bedded sandstone

The Hazel Greave[1] Grit is not developed in this area. The grey mudstones below the Holcombe Brook series pass down into black shales, in the lower part of which is a marine band containing *R. reticulatum*, mut. γ Bisat. A very hard band of calcareous ironstone occurs at the base of these shales, and is separated from the underlying Gorpley (Main Third) Grit by about 30 ft. of shale and mudstone which has yielded *R. reticulatum*, mut. (? β) and *Homoceras proteum* (Brown).

The beds between the Holcombe Brook Coal and the Gorpley Grit above described are well exposed in the vicinity of Scout Rock, south of Mossley, where the thickness is 250–300 ft.

Fossiliferous shales with *G. crenulatum* Bisat, probably representing the horizon of the Haslingden Flag marine band[2], have been discovered in the cutting east of Grotton Station, near Oldham. Confirmation of the exact horizon, however, lies in further field work to the north.

From the foregoing account it will be seen that the marine bands above the Kinderscout Grit in this district correspond closely in stratigraphical position with those observed in the area of the Rochdale Sheet.[3]

In the area mapped during the past year by Mr. Tonks, Millstone Grit occurs in a faulted inlier at Pilsworth Clough, south-east of Bury. Here the Sand Rock Mine was formerly worked, and the underlying Rough Rock was visible in the banks of the clough. Small isolated exposures of the shale above the coal can be seen at present. This blue grey pyritous shale is identical in character with that seen between the Sand Rock and Six Inch Mines at Smethurst Hall, north-east of Bury, and also with that proved in a boring in the centre of Bury. In the latter case 20 ft. of shale with a four-inch band of coarse siliceous sandstone separated the two coals. The thinning out of the upper leaf of the Rough Rock

[1] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 153.
[2] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 50.
[3] *Ibid.*

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previously described[1] continues, therefore southwards into this area.

Lower Coal Measures.—The sandstone subdivisions of the Lower Coal Measures referred to in last year's 'Summary of Progress'[2] have been found by Mr. Lloyd to hold good in the south-eastern part of the Sheet. The thickness of the Woodhead Hill Rock is maintained, and its coarse character persists. In the extreme south it splits into two coarse beds.

Between it and the Arley Mine five persistent sandstone beds have been noted, all of which are referable to horizons well known in the Rossendale anticline to the north.

The stratigraphical distance separating the Upper and Lower Mountain Mines in the Stalybridge district is about 210 ft. Southwards from Stalybridge the workable value of the Lower Mountain Mine decreases, and the Lower Yard or Bassy Mine assumes prominence and has been worked extensively south of Werneth Low.

There is visible on the southern slopes of the Etherow valley, around Stirrup Benches, a good section of Lower Coal Measures from the Bullion Mine marine band to the Woodhead Hill Rock. The Lower Mountain Mine is represented by a mere coaly streak.

The Lower Coal Measures of the Hyde district, north-west of Werneth Low, have never been proved by mining, though a narrow belt must exist, under a thick cover of boulder-clay, as a northerly continuation of the proved Lower Coal Measures of Romiley. It is probable, however, that only the Bassy Mine is of any economic importance in this area.

The Lower Coal Measures are only occasionally seen in isolated exposures in the area between Bury and Heywood, surveyed by Mr. Tonks. A good exposure of the Upper Foot Mine marine band occurs in the banks of the Roch above Bridge Hall Mills, east of Bury.[3]

The Ousel Nest Grit is brought in by faulting a short distance downstream from this latter exposure. The sandstones and shales of the Old Lawrence series are seen in the steep sides of the Roch, west of Heywood Sewage Works. The Riddle Scout Rock crops in the cutting immediately west of Heywood station.

It was pointed out by Hull[4] that, traced between Wigan and Heywood, the upper portions of the Lower Coal Measures are found to become increasingly arenaceous, flagstones replacing shales extensively. This variation from west to east has been observed by Dr. Sherlock to be well marked in the area between Bolton, Bury and Tottington.

North-west of Bolton a considerable spread of Horwich or

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[1] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 62.

[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 61.

[3] Hull, E., 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 19.

[4] 'The Geology of the Country around Bolton-le-Moors, Lancashire' (*Mem. Geol. Surv.*), 1862, p. 5.

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Ousel Nest Grit, which was formerly shown as Rough Rock, has been separated by Mr. Jones, and this interpretation has rendered necessary some fundamental changes in the map. The measures above are poorly exposed.

Considerable doubt appears to have existed as to the horizon of the two coals worked from Delph Hill across into the north-west part of Bolton. They were stated by Hull to be in the position of the Ganister or Lower Mountain Mine.[1] Boreholes to the south and the section at the existing colliery show that the thicker of the two seams is the Upper Mountain Mine, and that the 'Little Coal,' some 8 ft. above the Main Coal, probably represents the Cannel Mine of the Accrington district. Further proof is afforded by the discovery of a marine band in a stream section immediately north of Delph Hill which has also been recorded in No. 1 Chequerbent Pit,[2] where it lies about 60 ft. above the Upper Mountain Mine. At the Delph Hill exposure it consists of an extremely thin band of black shale containing *Pterinopecten* and occasional *Posidoniella*. This same marine band is exposed in a brick-pit in the north-west part of Bolton, the coals having been worked a short distance below the bottom of the pit.

From Delph Hill east to the Irwell Valley Fault the Upper Mountain Mine rests directly upon the Warmden Sandstone, whereas further south as much as 30 ft. of dark blue shale is found to separate the coal from the top of the sandstone.

The Crutchman Sandstone has been found to vary considerably in thickness. It has been extensively quarried at Delph Hill for flags. North-west of Bolton the overlying Pasture Mine appears to be absent, but is a workable coal to the south, below the Middle Coal Measures.

Middle Coal Measures.—The succession established in the Oldham and Ashton districts has been found by Mr. Lloyd to carry through into the Denton and Bredbury district with little variation. The four main sandstone horizons[3] above the Black Mine are visible in the very fine section along the River Tame west of Haughton Dale. The thick rock underlying the Sod Mine at Dukinfield and Ashton, mentioned in last year's 'Summary of Progress' as dying out to the north, is observed to fail also in a southerly direction, for at this horizon in the River Tame section only soft red mudstone and occasional sandstone bands are seen.

Enquiry has failed to reveal any evidence of the Arley (or Royley) Mine having been worked in the Woodley-Hyde district; and apparently no enterprise has been shown in the direction of shaft or tunnel driving, for the measures below the Woodley New Mine have not been proved. The Arley Mine is exposed in the railway cutting between Bredbury and Romiley at the west end of

[1] *Ibid.*, p. 6.
[2] *Trans. Man. Geol. Soc.*, vol. xxxi, 1910, p. 261.
[3] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 62.

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the tunnel, and the trend of its outcrop northwards, though concealed under drift, can be inferred from the exposure of the Old Lawrence Rock[1] at Woodley.

Two tectonic features of interest in the Oldham-Ashton area are the low hade (up to 60° from the vertical) of many of the faults, and the sudden development of complicated fault belts. The wide 'waste' or 'want' resulting from the former and the uncertainty involved by the latter necessitate enterprise and perseverance in the mining of this coalfield.

The following point of interest, an instance of which was afforded in the south part of the Oldham coalfield, arises when inclined strata are displaced by a normal fault. The stratigraphical displacement, as measured by the juxtaposition of known horizons on opposite sides of the fault, is less than the actual vertical displacement or true throw, and this discrepancy is correspondingly greater in the case of a fault with low hade.

The realisation of this fact in the driving of tunnels, where recognisable horizons are sought as guides, is consequently of practical importance where large faults are involved.

Exploration of the Middle Coal Measures has proceeded some distance westwards under the Permo-Triassic rocks from Ashton Moss Colliery, Ashton-under-Lyne; and a consideration of the levels in the Roger Mine workings, in conjunction with the surface evidence of borings, reveals a considerable cutting out of the higher Middle Coal Measures[2] by faulting and erosion prior to the deposition of the unconformable Permo-Triassic beds.

For reasons not too easy to follow, Hull took as the base of the Middle Coal Measures, in the Bury and Bolton districts, various horizons well below the Arley. One of the reasons cited[3] is a section in the Irwell north of Bury supposed to show an unconformity at the top of the Old Lawrence Rock. Mr. Tonks reports that the actual section is no longer visible, but that the examination of others in the neighbourhood suggests that the appearance of discordance at this horizon was illusory. At any rate the Arley Mine is identifiable in the district in question, although of poor quality and unworkable, and the beds below are referable to well known horizons of the Lower Coal Measures.

Further west in Dr. Sherlock's ground between Bury and Bolton the base of the Middle Coal Measures has on the other hand been placed too high. The strata between the Arley and Cannel Mines in the Middle Coal Measures are in this district, to a considerable extent, sandstones, and this led Hull to an erroneous correlation of the Hind's Mine of Radcliffe and Bury with the Arley, instead of with the Cannel Mine. It follows that some 732 ft. of strata formerly mapped, between Bolton and Bury, as Lower Coal Measures

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 47.
[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 62.
[3] 'The Geology of the Country around Bolton-le-Moors, Lancashire' (*Mem. Geol. Surv.*), 1862, pp. 6 and 7.

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are really Middle Coal Measures. The Arley Mine has not been worked in this area and is believed to be poorly developed, but its identification at Eagley, north-west of Bradshaw, enables a new subdivision of the beds to be made with confidence.

In Mr. Jones's ground west of the Irwell Valley Fault the base was again taken too low, this time at the Pasture Mine on top of the Crutchman Sandstone. This was apparently done on the analogy of the Irwell section mentioned above, as the Arley outcrop is correctly shown. The beds below this seam have now been referred to recognisable horizons in the Lower Coal Measures.

In the western part of this ground the *Carbonicola* bed below the Arley Mine has proved of much assistance in determining the crop of this coal.

The beds above this coal show very considerable variation when mapped from Eagley southwards to Daubhill, across the Irwell Valley Fault. In Eagley Brook a thick series of red, purple and grey sandstones, frequently with clay galls, and interbedded with grey and purple shale, is seen to overlie the coal. They are also visible in Astley Brook, south-west of Smithills Hall. Further south, at Daubhill, on the west side of the Irwell Valley Fault, these beds of sandstone, which appear to give the succession an abnormal thickness in this district, thin out and are represented by grey shale with only a few feet of grey sandstone.

East of the above fault the obscured and faulted sections of the beds between the Cannel Mine and the Arley Mine have rendered it extremely difficult to correlate and map with any great degree of accuracy the seams contained in these beds.

Upper Coal Measures.—The cutting of the main sewer tunnel in Rochdale Road, Manchester, is affording Mr. Tonks a splendid opportunity[1] of examining in detail the beds which were formerly exposed in the Irk valley. The cutting of the tunnel is not yet completed, so that it is not possible, at present, to enter into a discussion of the detailed correlation of these beds. The section has, however, been cut sufficiently far to show that the term 'barren' (*i.e.* of coal) applied by Hull[2] to this belt of strata is not strictly applicable. Hull followed Binney[3] in placing these so-called 'Barren Strata of the Irk Valley' below all the coals of the Bradford series; but as Hickling remarks[4], this could only be the case if the great St. George's Fault had no real existence. It seems probable that, on the completion of the section in the sewer tunnel, it will be possible to correlate these beds directly with some part of the Bradford series.

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[1] We are indebted to the Manchester City Engineers for affording ready facilities for the examination of this section.

[2] 'The Geology of the Country around Oldham' (*Mem. Geol. Surv.*), 1864, p. 37.

[3] 'Report on the Excavations made at the junction of the Lower New Red Sandstone with the coal strata at Collyhurst, near Manchester,' *Rept. Brit. Assn.*, Cork, 1843, p. 244.

[4] 'The Geology of Manchester as revealed by borings,' *Trans. Inst. Min. Eng.*, vol. liv, 1918, p. 383.

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The northern boundary fault of the Bradford coalfield has been proved in the tunnel at the junction of Plympton Street and Rochdale Road, about 400 yards south of the position provisionally assigned to it by Hull.

The uppermost bed of the Coal Measures in the tunnel, a pale red marl with ironstone bands, was unconformably overlain by the Collyhurst (Permian) Sandstone. The junction was irregular, with evidence of erosion of the marls prior to the deposition of the sandstone. This observation does but confirm that made long ago by Binney, who examined this junction at Collyhurst and at Ardwick.[1]

Dr. Sherlock remarks that while it is customary to take the boundary between Middle and Upper Coal Measures at the Worsley Four Feet Mine it should be understood that this line is arbitrary as there is no essential lithological distinction between the beds above and below. Reddish sandstones and mottled shales such as normally characterise the Upper Coal Measures occur also well beneath the Worsley Four Feet.

Permo-Trias.—As is shown in the published map (89 S.E.) the Irwell Valley Fault throws a tongue of Permo-Triassic rocks northwestward as far as Ringley. Dr. Sherlock points out that the Collyhurst Sandstone, the lowest member, has not been seen between Ringley and Molyneux Brow and it is probable that it does not extend so far to the north-west as was supposed, for, although the ground is thickly covered by superficial deposits, Upper Coal Measures sandstone is visible in this area in three places adjoining the railway embankment, on ground formerly thought to be on the Collyhurst and 'Permian' Marl crops. Between the railway and the Bunter crop there is no room for both the 'Permian' Marl and the Collyhurst Sandstone, and the former is known to be present. The 'Permian' Marl is still to be seen in two trivial sections on the north side of the Manchester and Bolton Canal opposite Dixon Fold Station, but drift and landslips hide the remainder of the crop.

Bunter Sandstone is well exposed in the banks of the River Irwell for a considerable distance. It is a red sandstone with abundant millet-seed grains and in part cross-bedded. Pebbles occur sporadically, but the pebble-bearing sandstone is quite subordinate to the non-pebbly rock in which it forms lenticles. The greater part of the Bunter has the characters of the Lower Mottled Sandstone, but in view of the presence of pebbly lenticles it seems best to call the rock Bunter Sandstone without attempting an impossible separation into two divisions. The junction with the 'Permian' Marl below is not seen, but elsewhere in the Manchester area there is a passage between them, and it is significant that the Bunter Sandstone nearest to the marl sections is mottled and free from pebbles, *i.e.*, is of Lower and not Middle Bunter type.

[1] 'On the Permian Beds of the North West of England,' *Mems. Lit. and Phil. Soc. Manch.*, series 2, vol. xii, 1855, pp. 220 and 229.

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Mr. Tonks wishes to take the opportunity of introducing local nomenclature for the marls with limestones which occur above the Collyhurst Sandstone and have previously been called 'Permian' Marls. In view of the fact that evidence is accumulating to show that these beds and their correlatives are not strictly Permian in age, it seems better that this term should be dropped. It is proposed to call these marls with limestones the Manchester Marls, Manchester being the area in which they occur in their fullest development and are best known.

The Manchester Marls have been proved beneath the drift in the Rochdale Road sewer tunnel for a distance of 250 yards north of the junction of Central Avenue and Rochdale Road. Their presence here, hitherto unsuspected, provides evidence of the continuation in this direction of faults known to be present in Newton Heath. The Collyhurst and Bunter sandstones have been examined in various artificial sections in the city. As previous workers have remarked, it is difficult to distinguish between the two rocks in hand specimens, but in the mass certain broad distinctions can be drawn. The colour of the lower rock is usually a brighter red than that of the Bunter; and it is free from pebbles, whereas pebbles of considerable size occur in some beds in the lower part of the Bunter. The superior degree of sorting to which the sands forming the Collyhurst were subjected is shown by the remarkable evenness of grain in any one bed in the rock. In the Bunter Sandstone, on the other hand, coarse and fine grains are often seen together in the same specimen. The distinction between these two sandstones and the red sandstones of the Upper Coal Measures is comparatively easy in this area. The red colour of the latter rocks usually has a greyish or purplish tinge, variations in shades of colour are frequent, and these beds are much harder and harsher than the overlying Permo-Triassic sandstones.

W. B. WRIGHT.

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5. CUMBERLAND DISTRICT

Headquarters: Whitehaven

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E. E. L. DIXON, A.R.C.Sc., B.Sc. } Senior
T. EASTWOOD, A.R.C.Sc. } Geologists.
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WHITEHAVEN AND MARYPORT SHEETS

THE survey of the West Cumberland Coalfield has been continued northwards from Workington by Mr. Eastwood, and much of that part about and beyond Maryport (Sheet 22) has been completed. During part of the field season he was engaged upon a joint drift survey of six-inch map Cumb. 72 S.E. (Sheet 37) with representatives appointed by the Ministry of Agriculture.

Mr. Dixon has been engaged in advancing work on six-inch maps by gathering information about mines and explorations for ore and coal in the Skiddaw Slates and Carboniferous rocks of his area in Sheet 28 (Whitehaven), concurrently with a certain amount of necessary field work.

Dr. Smith and Mr. Eastwood dealt with several enquiries about geological problems in the district, and have completed more of the six-inch maps, covering extensively mined areas, in Sheet 28.

Progress has been maintained in the collection of other mining information, boring records, and the examination of cores of new borings.

Skiddaw Slates.—The mineral veins and the Skiddaw Slates of Kelton and Knock Murton Fells, lying east of Kirkland (Sheet 28) have been studied intensively by Mr. Dixon, who has now gathered all the field evidence available and also examined the plans of old hæmatite mines. His conclusions, deduced from this work, as to the probable origin of the ore are not yet fully matured.

Carboniferous Limestone Series.—Further study of the Carboniferous Limestone Series below the First Limestone, and of the mines therein, has been made by Mr. Dixon in the ground between Dean and Frizington. Amongst the suite of photographs now available of the Carboniferous Limestone of Sheet 28 there are a number showing phenomena pointing to the shallow-water conditions that occurred at certain stages during its formation[1] (Plate V).

Beds of the Snebro Gill type[2] in the Hensingham Group of the Carboniferous Limestone Series crop out in the bed of the River Ellen, at Ellen Grove, near Ellen Bank, Maryport. Mr. Eastwood notes that to the south-west they are faulted against Coal Measures near the horizon of the Yard Band; whilst, beyond concealed

[1] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 53.
[2] Eastwood, T., in 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 64.

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ground to the north-east, dark shales and sandstones, varying from hard and fine to soft and coarse, associated with a thin coal, make their appearance. These latter may be seen along the River Ellen as well as in the gully north of, and in the railway cutting east of, Birkby Mill, ¼ m. east of Ellen Grove—in every

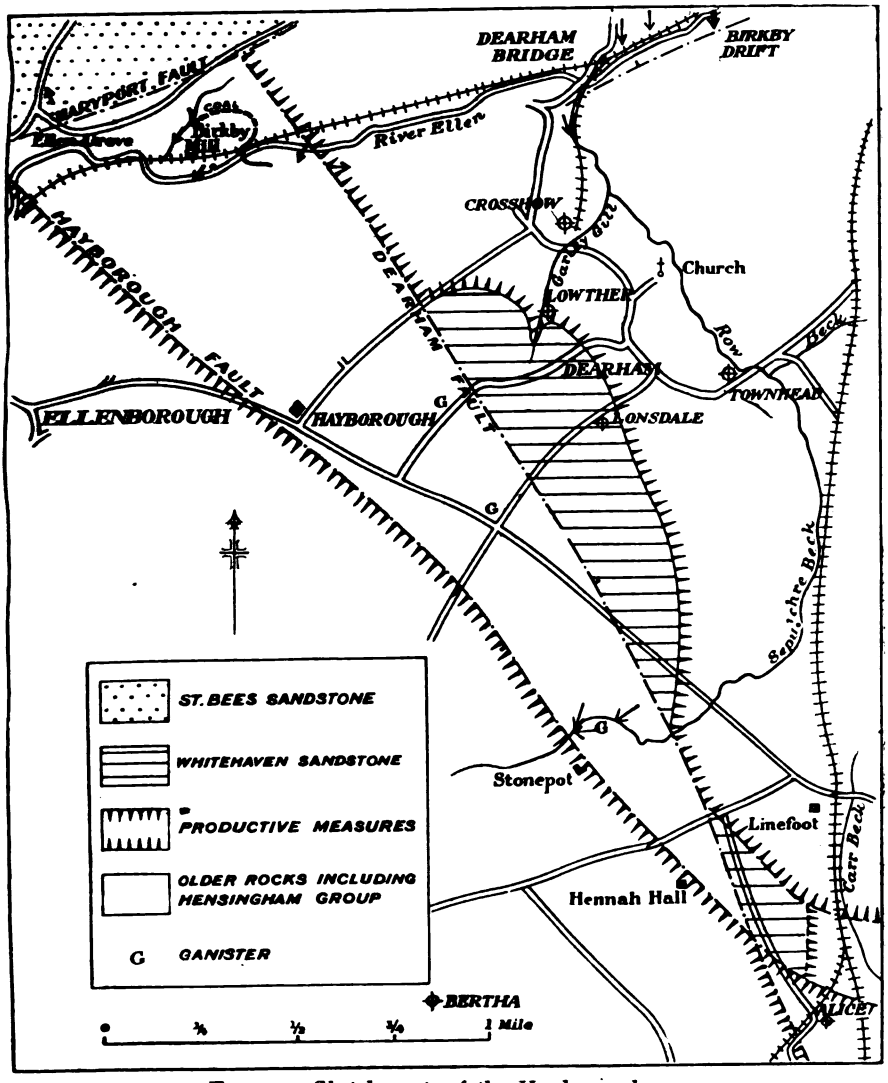

FIG. 4.—*Sketch map of the Hayborough area.*

case dipping to the south-west. They have, as yet, yielded no fossils *in situ*, although a loose block of decalcified limestone of Snebro Gill type was found in the above-mentioned gully. If there is no faulting the beds belong to the Hensingham Group; if they are Coal Measures they must occur low in the sequence.

In a ravine 600 yds. east of Birkby Mill, and south of the Ellen,

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the beds just described are terminated by a N.W.-S.E. fault, introducing Main Band Rock dipping east at varying angles. Part of the Main Band was got here during the coal strikes of recent years by sinking shallow shafts through the sandstone. The fault courses south-westward by Dearham Colliery to beyond Alice Pit, 1 mile west of Dovenby (Fig. 4); and, with the above-mentioned fault near Ellen Grove, encloses a wedge-shaped belt of strata which is rather more than half a mile in breadth on the north-west at the Boundary or Maryport Fault,[1] and extends south-eastward through Hayborough to near Alice Pit where the faults converge. In the southern half of this belt hard fine-grained sandstones akin to ganister, such as are unknown in the Productive Measures, were formerly quarried on a small scale about 600 yds. north-west of the Commercial Inn at Lonsdale Place, Dearham. Similar rock appears in the old tramway cutting 70 yds. west of the inn, and again farther south in Sepulchre Beck near Stonepot Farm.

The age of some of the rocks in this belt of strata, previously mapped as Coal Measures, remains to be settled, but in any case the coals commonly worked in the district cannot be expected to be present.

Coal Measures.—From Dearham Bridge Station to the ravine towards Crosby, beyond Birkby Colliery, strata from above the Little Main seam down to the Upper Three-quarters Coal[2] are exposed along the River Ellen and in the railway cutting, dipping south and south-west.

The Upper Three-quarters Coal, with a dark shale roof succeeded by sandstone and sandy shales, occurs near the foot of the above-mentioned ravine. Two other coals, of which the lower is probably the Lickbank, are exposed in the railway cutting at Birkby Colliery. The measures between these two coals consist mostly of coarse sandstone—in part with fragments of quartz, ¼ in. in diameter—somewhat similar to the Four Foot Rock of Harrington and Whitehaven, which, however, occurs at a much lower horizon.

The outcrop of the Little Main seam is masked, but the overlying sandstone may be seen on the north side of the valley between Birkby Colliery and the station. In the southern part of the coalfield the measures immediately above the Little Main seam are usually bluish mudstones, but in parts of the Maryport Sheet (22) fairly thick and coarse sandstones occasionally take their place. It is noteworthy that in such areas the Little Main is subject to 'nips' in which the roof cuts out the coal (*cf.* those in the Main and Bannock Bands where the roof is a sandstone).

Immediately south of, and parallel to, the River Ellen the Birkby Fault,[3] an upthrow south, repeats some of the outcrops.

[1] This fault throws in St. Bees Sandstone to the north of the exposed coalfield.

[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, Fig. 4, p. 73.

[3] One of the Birkby drifts, beginning in measures at about the Little Main horizon, passed southwards through this fault into the Upper Three-quarters Coal—here a seam about 2 ft. in thickness, characterised by an abundance of vitrain and clarain with partings of fusain and comparatively little durain.

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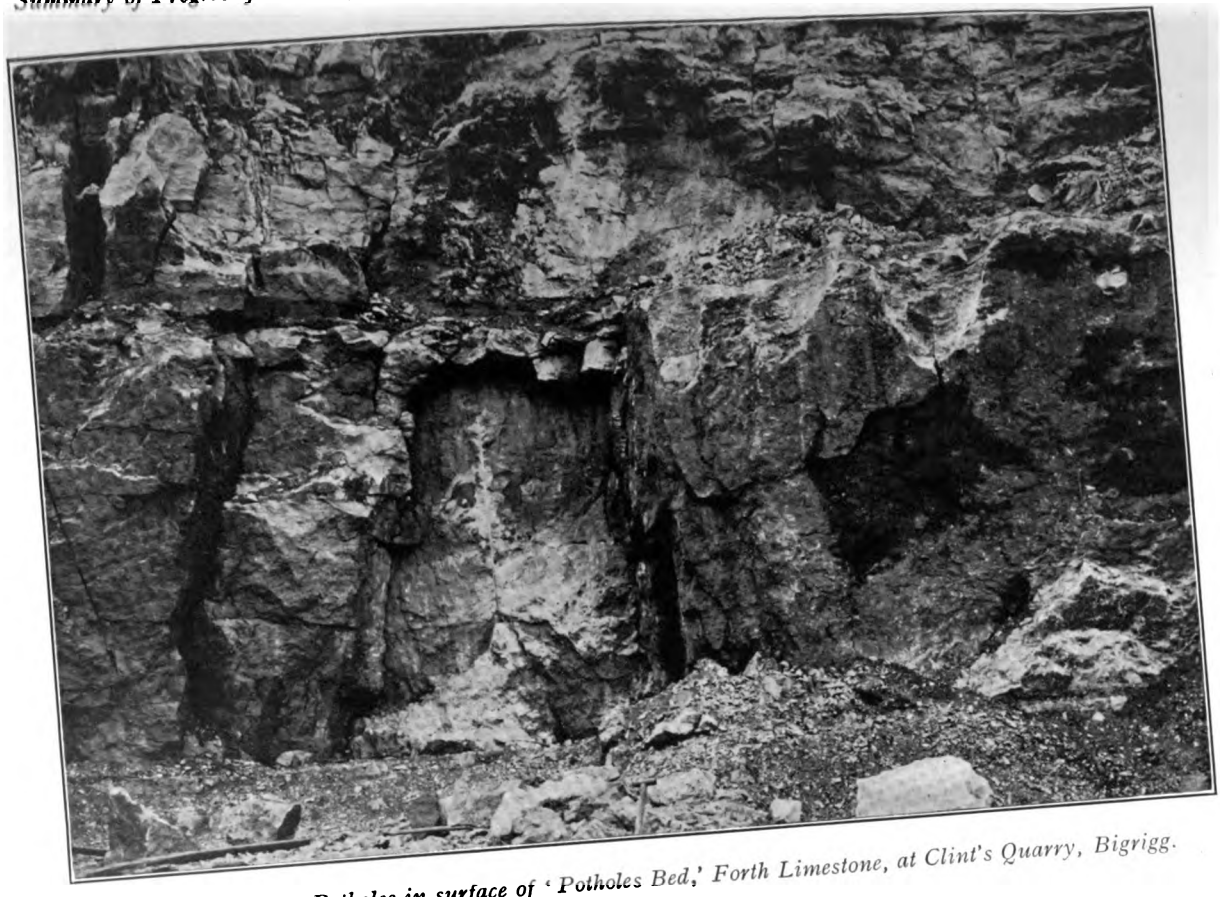

Contemporaneous Potholes in surface of 'Potholes Bed,' Forth Limestone, at Clint's Quarry, Bigrigg.

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The sandstone above the Little Main seam was quarried about midway between Dearham Bridge and Crosshow Colliery, north of Dearham, along the course of the Row Beck which flows northwards to the Ellen from near Townhead. Farther upstream, and near the foot of Garley Gill (a stream from the old Lowther Pit), there is an outcrop of a coal at or near the Yard Band horizon; while still farther upstream the Cannel Band crops out north of Dearham Church and was worked during the strike of 1921 between the church and Garley Gill. In the higher part of this gill measures from the Ten-quarters Coal to the Whitehaven Sandstone are visible at intervals. South of Dearham Church the southerly and south-westerly dip brings on measures—chiefly bluish mudstones with thin sandstones—ranging up to and slightly above the Ten-quarters Coal, as far as a point near Townhead, where a fault causes the Cannel Band to be thrown up to river-level.

South of Townhead Glacial Drift floors the streams, but the valley of the Sepulchre Beck, from Townhead, Dearham, to near Linefoot, marks the approximate outcrop of the Cannel Band. The measures here have a westerly dip.

South of Linefoot there is considerable faulting near Alice Pit and measures extending up to the Whitehaven Sandstone make their appearance.

In last year's 'Summary' [1] the correlation of seams in the lower half of the Productive Measures north and south of the River Derwent was given. Here the upper seams of the Workington-Maryport area are dealt with by Mr. Eastwood, as in this district they attain their best development and have been worked to a greater extent, either alone or in conjunction with fireclays, than farther south.

The Ten-quarters Coal, equivalent to the Moorbanks of Workington, to the Spar or China Band of Studfold and Oatlands, and the Five-Foot of Cleator Moor, may be taken as the base of this upper series of coals. The generalised sections (Fig. 5) illustrate the correlation in the district now under consideration, but the linking up of that district with the Whitehaven–Cleator Moor area is not attempted at present.

Although in places parted by dirt, the Ten-quarters Coal is usually a better and a thicker seam than those above. The Slaty Band is generally split up by bands of shale or 'slate' which are in places so numerous as to render the seam useless, yet it occasionally yields several feet of good coal. The other seams, of which the White Metal Band is probably the most important, call for little comment at this stage.

The Whitehaven Sandstone (shown stippled in the sections, Fig. 5) is unconformable to the Productive Measures, and is proved to cut out several coals as it is traced from place to place.

The seams in the 200 ft. of strata between the Brassey and the

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 73-5.

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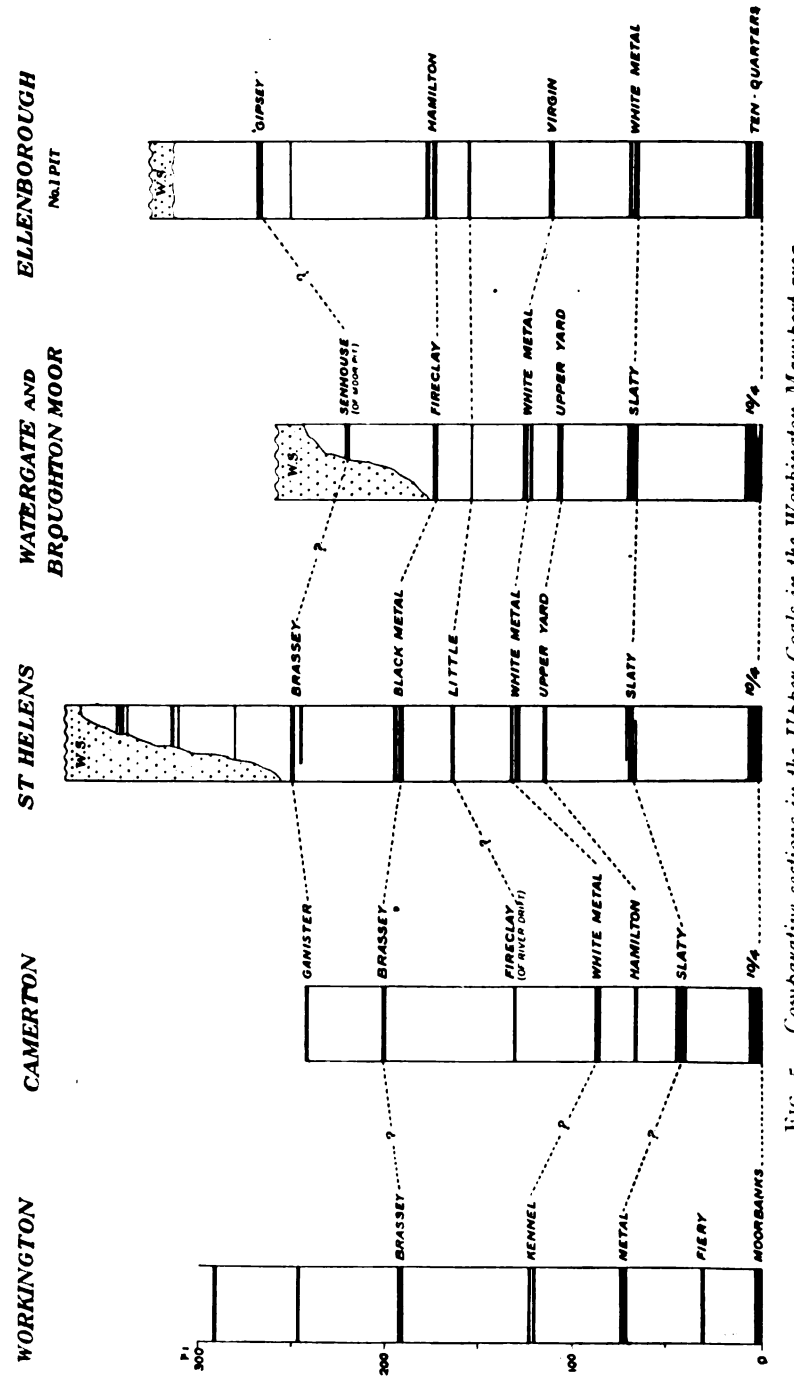

FIG. 5.—*Comparative sections in the Upper Coals in the Workington-Maryport area.*

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Moorbanks coals were worked at several of the old collieries in the central and Banklands districts of Workington up to about the middle of last century, when coal-mining ceased in those areas. The Kennel Band and Metal Band of Workington should not be confused with the splits of the Main Band, carrying similar names, in the district to the east and north of that town.

At Camerton Colliery, in what is known as the 'River Drift' area, the productive belt of strata above the Ten-quarters Coal amounts to about 250 ft. in thickness. Since no shaft or borehole penetrates the series the section[1] (Fig. 5) has been compiled from levels taken off mine-plans and from drifts. In addition to the one shown, a second 'Fireclay Coal' is worked at Camerton in lower measures.

The section entitled 'St. Helens' may be regarded as an average section for an area of about three square miles, comprising Moorhouse Guards and old and new St. Helens collieries. All the seams from the Brassey Band downwards have been worked to a considerable extent at Moorhouse Guards and old St. Helens; but, with the exception of small patches, the seams above the Ten-quarters Coal remain untouched over large areas. The Black Metal Band is sometimes referred to as the Brassey Band around old St. Helens. The higher seams are, as yet, nameless and unwrought.

In the Watergate-Broughton Moor area the Ten-quarters Coal, Slaty Band, Upper or Top Yard Coal and White Metal Band are fairly constant in occurrence, and are undoubtedly the same seams as those worked under similar names at St. Helens. Most of these have been worked to outcrop on Broughton Moor.

The Senhouse Band shown in the section is a pyritous coal worked in conjunction with fireclay at Moor Pit. It should not be confused with the coals of the same name worked at Watergate and Ellenborough Collieries, for these coals occur well above the base of the Whitehaven Sandstone Series. It is tentatively correlated with the Gipsey seam of the latter colliery.

At Ellenborough Colliery new or old names for the seams are introduced somewhat haphazardly. The White Metal Band of that colliery is certainly the Slaty Band of other places; while the Virgin Coal is probably equivalent to the White Metal Band elsewhere, and the Hamilton Coal to the Fireclay Coal or Black Metal Band.

The Maryport or Boundary Fault has been fairly closely located by Mr. Eastwood below high-water mark on Risehow Scar, south-west of Maryport, where it brings buff Triassic sandstones against much disturbed rocks of the Whitehaven Series. Thence, to the north-east it is concealed by superficial deposits, but must run near the Carlisle road through Birkby, since at Ellen Grove Snebro Gill Beds occur in the River Ellen (p. 72) and red St. Bees Sand-

[1] We are indebted to Mr. J. Turnbull of Camerton Colliery for supplying the requisite data.

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stone is exposed in old quarries about 200 yds. to the north-west. Beyond Birkby the fault probably lies about 350 yds. south-east of the main road at Crosby.

Triassic Rocks.—Mr. Eastwood finds that the St. Bees Sandstone, like the Carboniferous rocks from which it is separated by the Maryport Fault, is heavily covered by Glacial drift. Good sections may be seen in the cliffs and on the beach at Maryport, but exposures are rare farther north.

Apart from that of Risehow Scar, already noticed, most of the St. Bees Sandstone is of the typical red colour, although occasional bands of shale and sandstone are present. The dip is usually northerly, but considerable variations occur and beach sections show some faulting—of what magnitude it is impossible to estimate.

Raised Beach and Storm Beach.—From Workington northwards the coast is fringed by raised beach reaching an elevation of from 25 to 30 ft. above O.D., but sloping imperceptibly into the present beaches. South of Maryport the modern fringe is growing by the accumulation of storm beach mostly derived from the refuse of iron and coal undertakings. North of Maryport, especially around Bankend, although slag occurs on the beach, the sweep of the tides has removed a strip of the raised beach several yards wide in recent years.

Brampton Sheet

Mapping in this Sheet (18) has been continued by Messrs. Trotter and Hollingworth. The western margin of Sheet 19 and the northern margin of Sheet 24 also have been entered.

Mr. Trotter examined the ground on an east to west line from Gilsland to Smithfield, and in the South Tyne valley around Harper Town; whilst Mr. Hollingworth was engaged on the Pennine escarpment east of Castle Carrock, Cumrew and Croglin (Sheet 24), and a drift-covered area of Permian and Triassic rocks south-east of Carlisle.

Numerous mining plans (coal and gypsum) have been examined.

Lower Limestone Group.—This group and 1,200 ft. of strata in the underlying Seminula Zone, neither of which have been described hitherto, are discussed by Mr. Trotter in Appendix II. The Seminula Zone has not been recognised in Northumberland, nor has it been detected within the limits of Sheet 18 south of Castle Carrock, although it occurs farther south in the Westmorland Pennines.

The base of the Lower Limestone Group has been fixed by Mr. Trotter, on palæontological grounds, at the base of the Lower Dibunophyllum Zone, D_1, that is to say at a horizon different from that of the base of the group in north Northumberland, where perforce the group is separated as a unit from the freshwater Scremerston Coal Group, the higher members of which may represent

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the lower part of the Lower Limestone Group of the Brampton district.

On the escarpment between Castle Carrock and Croglin Mr. Hollingworth has found evidence showing the progressive splitting up of the thick Melmerby Scar Limestone as it is traced northwards. The change is heralded by the lateral replacement of the thick pale pseudo-brecciated, and in part algal, limestones forming the upper part of the Melmerby Scar Limestone in the Westmorland Pennines and in Trowslinn Gill, directly east of Cumrew, by dark blue-grey, massive to earthy limestone, with two posts of pale nodular limestone weathering cream-coloured, in the River Gelt. Concurrently with this change beds of shale and subordinate sandstones appear within the main mass of the limestone and thicken northwards.

The poorly exposed sandstones and shales, with one or more thin limestones, lying between the Melmerby Scar Limestones and the red Basement Conglomerates,[1] also appear to thicken northwards (Fig. 6). These beds may represent part of the sequence exposed in Castle Beck, Naworth (Appendix II, p. 157), the lower part of which, however, is probably absent here.

A thin coal below the Melmerby Scar Limestone has been worked for household use near Brackenthwaite, 1½ m. north of Cumrew.

Middle Limestone Group.—In Mr. Trotter's ground *Girvanella* (Fig. 16) occurs in a limestone near Scarrow Hill, N.E. of Naworth Station. It is not abundant and becomes scarcer as the limestone is traced eastward; yet it has been found at Lodges and in a beck ¼ m. north of Temon.

North-east of the Low Row district, where the group is exposed, there lies a large drift-covered expanse, beyond which is the Tipalt Burn, in which the Tyne Bottom Limestone has been identified ¼ m. east of Wood House; and here, as elsewhere in the district, it yields *Saccamina carteri* Brady. Although not confined to this horizon (*see* below), the same as that at which it occurs in Garwood's 'North-Western Province'[2], its presence in abundance over such a wide area is of value.

The Scar Limestone, both at Low Row and in the Tipalt Burn, where it is only 12 ft. thick, contains cherts, and is underlain by a coal-bearing horizon. Cherts occur throughout the district in the Four Fathom Limestone.

The base of the Dibunophyllum sub-zone, D_2, as determined by the *Girvanella* band, has been found by Mr. Hollingworth in the first limestone above the Melmerby Scar, at a number of points between Albyfield and Newbiggin. It has not been definitely identified in the Gelt section and there is some doubt as to its probable position, but a comparison of the lowest part of the succession in Croglin Water with that occurring in the Gelt

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 77.

[2] 'The Lower Carboniferous Succession in the North-West of England,' *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, pp. 482–3.

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suggests that practically the whole of the Middle Limestone Group is exposed by the former river.

The group is greatly reduced in thickness when compared with the succession established in the north of the Sheet[1], and varies considerably in detail. Here, for example, *Saccamina* occurs not only in the Tyne Bottom Limestone, but abundantly near the top of the Scar Limestone, in the Four Fathom Limestone, and occasionally in the Great Limestone.

A number of thin coals are included in this group: one, probably the Hynam Coal, has been worked at several points on its outcrop east of Geltsdale House, and attempts to exploit other small seams have been made in the neighbourhood of Croglin. A coal, averaging 1 ft. in thickness, lying below the Four Fathom Limestone, north-east of Croglin Water, was successfully mined for several years for lime-burning.

Upper Limestone Group.—The thickness and sequence of this group has been established by Mr. Trotter and may now be compared with that of north Northumberland (Fig. 6). The true thickness, 1,400 ft., is almost twice that formerly supposed, and the Little Limestone Coal lies approximately 1,470 ft. below the lowest seam of the Coal Measures—the Low Main—instead of 850 ft. as previously thought. At the time of the old survey the great (but actually normal) thickness of the strata in the Denton Fell district was explained away by repeating the outcrop by a supposed large fault, occupied by a roughly E.–W. whin dyke, and throwing down northward. This fault appears to have no existence, for the workings in the Little Coal from Blenkinsopp Colliery, near Greenhead, have been carried through, and beyond, the dyke.

The Great Limestone of Angerton quarry, Greenhead, is recorded by Dr. S. Smith[2] as the Four Fathom. It contains no cherts and is followed by the 'Great Shale'; hence it appears that it was indicated correctly upon the old one-inch geological map (18).

The Little Limestone, with its coals, has been traced across Denton Fell to Blenkinsopp Colliery, where the limestone attains an exceptional thickness of 48 ft., as against an average of 20 ft.

This limestone occurs south of the Stublick Fault, which forms the southern boundary of the Midgeholme coalfield, in the South Tyne valley. The two underlying coals, exposed near Tows Bank, are 8 in. and 1 ft. thick respectively, and have been converted into cinder coal by the intrusion of an overlying whin sill; nevertheless both coals are used locally for domestic purposes, and are smokeless.

In the same neighbourhood the Oakwood Coal crops out 300 ft. above the Little Limestone. This coal occurs in the western Pennine escarpment and has been proved in a boring on Denton Fell. There seems no doubt that it is fairly persistent throughout the

[1] Trotter, F. M., in 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, Fig. 3, p. 72.

[2] 'Report . . . on the Carboniferous Limestone Formation of the North of England,' *N. of Eng. Inst. Min. and Mech. Eng.*, 1912, Newcastle-upon-Tyne, p. 63.

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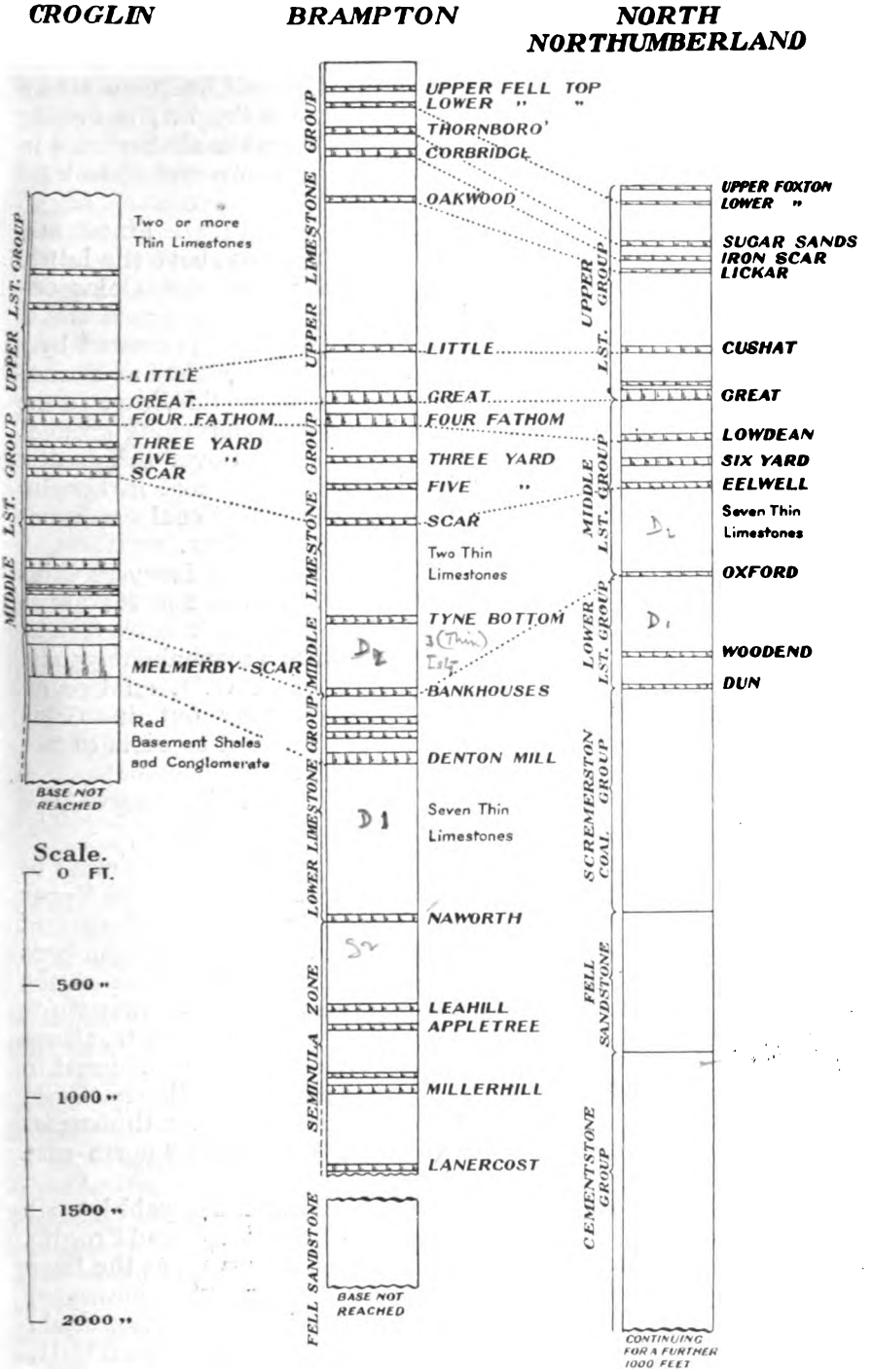

FIG. 6.—*Comparative vertical sections of the Carboniferous Limestone Series of East Cumberland and North Northumberland.*

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district. It is equivalent to the Lickar coals of Northumberland, and probably to the Firestone Sill Coal of Alston.

Mr. Hollingworth reports that the Upper Limestone Group appears to be at least 800 ft. in thickness east of Croglin; but owing to the absence of borings and definitely recognisable horizons in the higher beds it is difficult to piece together or correlate isolated sections.

A thin limestone occurs between the Great and Little limestones, and others at 300 ft., 450 ft., and higher horizons above the latter. These are probably attenuated representatives of the Oakwood–Felltop group of Northumberland.

In Croglin Water the Little Limestone Coal is represented by a number of seams a few inches thick. It has been worked at Burned Edge Mine to the south of Croglin Water and up Old Water to the north. Little information is available in the intervening ground. The presence of whin sill near the coal horizons over the greater part of the area and the poor development of the coal in Croglin Water render the possibilities of finding workable coal somewhat small. Unsuccessful trials tend to confirm this view.

A 1-ft. coal has been dug for household use near Lawyers Cross (Sheet 24) at the head of Croglin Water. It lies 200 ft. above the Little Limestone.

An unsuccessful attempt was made to work a seam about 350 ft. above the Little Limestone at 1,750 ft. above O.D. on Croglin Fell. This seam appears to be that cropping out in Great Bleaberry Gill, 1 mile N. of Croglin Fell, where it consists of two 1-ft. seams separated by 1 ft. of coaly shale.

Thin coals corresponding to the Oakwood and a higher seam have been noted in the headwaters of Old Water in Geltsdale.

Millstone Grit.—Mr. Trotter finds that arbitrary lines must be drawn for the boundaries of this formation. Shales above the Upper Felltop Limestone in Hartley Burn near Burnfoot, north-east of Midgeholme, yielded fossils identified by Mr. J. Pringle as from beds high up in the Carboniferous Limestone Series. The base of the Millstone Grit is drawn, therefore, at the bottom of the first thick sandstone above these fossiliferous shales, *i.e.*, about 110 ft. above the Upper Felltop Limestone. The Low Main Coal is considered to form the base of the Coal Measures; hence the Millstone Grit, consisting of sandstones, shales and thin coals, is 270 ft. in thickness. Two of the coals crop out in Kellah Burn, nearly 2 miles north-east of Midgeholme.

In the area mapped by Mr. Hollingworth a coarse pebbly grit caps much of the high ground at the head of New Water and Croglin Water. This was taken, at the time of the last survey, as the base of the Millstone Grit. Lithologically similar grits, however, appear at lower horizons in the sequence. The underlying shale contains an earthy coal in the neighbourhood of West Dun Hill.

Coal Measures.—The Coal Measures of the Midgeholme

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Field have been traced eastwards by Mr. Trotter from Haltonlea Gate to East Coanwood (Sheet 19). As the rocks are covered by Glacial drift, all the information has been obtained from colliery officials and old plans.

The Low Main Coal[1] has been worked neither at Lambley nor Coanwood, but is known to be 22 in. thick in the former district. Farther east, 300 yds. north of Lanehead, a line of old workings indicates its outcrop. At East Coanwood its thickness is 14 in. A trial shaft, 20 ft. deep, was sunk to the coal recently, but the coal was not worked.

The Slag and overlying Wellsike seams vary in thickness between narrow limits, the former averaging 5 ft. and the latter 4 ft. In past times both have been wrought extensively throughout the coalfield for coking purposes.

The Three-quarters seam of Lambley is known as the Yard and the Tindale coal at West Coanwood and Featherstone collieries respectively. It thins eastward and is correlated with the One Foot Coal of East Coanwood.

Overlying the two Craignook seams is the Craignook Sandstone, which has been traced from Midgeholme to Harper Town, but disappears east of the South Tyne. At West Coanwood a 70-ft. bed of sandstone comes in beneath the higher coal, its upper layers having replaced the Lower Craignook seam. Both lower and upper seams are present at East Coanwood where they are termed respectively the Yard and Five Quarters.

The correlation is as follows:—

Midgeholme	*West Coanwood*	*East Coanwood*
(Thick Sandstone)		
Upper Craignook	Five Quarters	Five Quarters
Lower Craignook	(Thick Sandstone)	Yard
Three Quarters	Yard	One Foot Nine
Wellsike	Coom Roof	Coom Roof
Slag or Great Midgeholme.	Seven Quarters	Slag
Low Main	———	Cannel

Whin Sill.—Intrusions of whin sill occur principally at two horizons in the area surveyed by Mr. Hollingworth. It attains a thickness of 80 ft. in Old Water and New Water, where it occurs near the horizon of the Little Limestone, but appears to thin westward in the direction of the Carboniferous Limestone escarpment.

In Croglin Water the whin lies directly beneath the Scar Limestone, being represented by two 20-ft. sills separated by 6 ft. of hardened shaly sandstone at the head of a picturesque gorge some 200 yds. in length. When seen again in the Scar Limestone quarries, ¼ m. north-east of Fieldhead, it is 10 ft. or less in thickness, being intruded into the upper part of the limestone. In the quarry face it gently trangresses northwards to lower horizons, splitting up into two or three minor and diminishing sills.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 78.

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An inlier occurs in the headwaters of Black Burn, 1 m. east of Cold Fell, several hundred feet above the Little Limestone.

Penrith Sandstone.—The Penrith Sandstone is well exposed in the valley of the Eden between Holmwrangle (Sheet 24) and Edenbrows, and in the Petteril gorge between Bolton House and Howgill, ¼ m. south of Springfield. It is usually a red, soft, highly false-bedded, millet-seed sandstone without secondary silicification. Mr. Hollingworth finds that these are the most northerly exposures of the Penrith Sandstone of the Eden valley, and possess several points of interest, the second occurrence described below having a direct bearing upon the relationship of the Permian to the Trias.

An old river cliff, ½ m. north of Holmwrangle, shows bands of coarse conglomerate, up to 10 ft. in thickness, interbedded with Penrith Sandstone containing bands of red micaceous shale. The conglomerates, which are frequently lenticular, are composed almost exclusively of pebbles of Carboniferous limestone, up to 6 in. in diameter; exceptions being pebbles of Carboniferous sandstone.

In a tributary of the Petteril, 500 yds. south of Springfield, the uppermost beds of Penrith Sandstone have an even-bedded water-deposited appearance. They pass upwards into St. Bees Shale with bands of sandstone of St. Bees type by the gradual incoming of shales and the intermittent occurrence and final disappearance of millet-seed grains.

St. Bees Shales.—Between the Eden and the Petteril this formation is of considerable importance because it includes thick workable beds of anhydrite and gypsum which appear to occur about 30 ft. above its base. In the past gypsum has been quarried at many points along the outcrop between Duncowfold, east-north-east of Cotehill, and a point ¼ m. south of Springfield; but the Cocklakes Mine is now the sole producer in the area surveyed. Recent developments there indicate that the supposed fault shown south of Acrehead on the old one-inch geological map (106 S.W.), if indeed it exists, must lie considerably farther north. The removal of the thick central bed of anhydrite[1], which now finds a ready sale in the manufacture of ammonia, greatly facilitates the working of the upper bed of gypsum.

The St. Bees Shales, with associated gypsum, have been proved in borings at a number of points near High Stand, south-east of Cotehill, within the area originally mapped as Penrith Sandstone.

St. Bees Sandstone.—The St. Bees Sandstone forms a series of fine river-cliffs between Brackenbank and Wetheral. Quarrying is in progress on a small scale near Wetheral, but the extensive Newbiggin quarries are now disused. In an old quarry near Newlands a yellow and red variegated variety was obtained, which

[1] Smith, B., *in* 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. iii, ed. 2, 1918, pp. 12–13.

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appeared to correspond lithologically with the variegated Kirklinton types known farther north.

Armathwaite Dyke.—Mr. Hollingworth reports that old quarries in the Armathwaite dyke at the north-east end of Barrock Fell (Sheet 24) have been reopened for road metal. The exposures show that at this locality the dyke dies out upward and spreads out as a series of sills intruded along the bedding planes of the Penrith Sandstone.

Glacial.—Near Gilsland the River Irthing enters a drift-filled pre-Glacial valley which it roughly follows westward, in places occupying it in such a way that the new valley is cut entirely in glacial deposits. From evidence gathered by Mr. Trotter this old valley also appears to have drained towards the west from some point lying to the east of Gilsland.

A glacier-lake was held up in the South Tyne valley during the retreat of the western ice-sheet, the spur between that valley and Allendale (Sheet 19) being trenched by overflows which drained eastwards at heights of 730 and 600 ft. above O.D.

Deltas from land streams lie in the former valley at 550 and 600 ft. above O.D.

On the high ground farther south-west Mr. Hollingworth finds that the western ice, with mixed Lake District and Scottish erratics, overrode the watershed between the Eden valley and South Tyne drainage areas. Additional marginal drainage phenomena have been observed on the Pennine escarpment.

On the lower ground in the west of the Sheet sand and gravel mounds and deltas, of mixed Scottish and Lake District origin, apparently of earlier date than the last advance of the ice, were detected by both surveyors.

BERNARD SMITH.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters: Newcastle-on-Tyne

R. G. CARRUTHERS, District Geologist.
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IN Northumberland work was continued on the Old Red Sandstone lavas of the Cheviots, and on Carboniferous rocks ranging from the Calciferous Sandstone Series up to Lower Coal Measures.

Mr. Burnett dealt with the lavas on the north-west side of the Cheviot massif, the survey of one-inch Sheet 3 being completed. Sheet 6 (Alnwick) was also finished, the small outstanding area south and west of Alnwick being done by Mr. Maden and Mr. Anderson. Subsequently Mr. Anderson took up work on the south-west side of the Cheviots, Mr. Maden returning to the Coquet valley. Mr. Fowler finished his revision of the Rothbury-Broomhill district, and then moved south to Morpeth.

In addition to the normal programme of field-work a small area well adapted as a test in soil-mapping was surveyed in the Upper Coquet valley, round Holystone; for this purpose Mr. Anderson worked in collaboration with Mr. W. L. Davies, of University College, Reading.

Silurian.—Amongst the Cheviot lavas, on the south-east side of the massif, two small inliers, provisionally assigned to the Silurian, are shown on the published map (one-inch Sheet 6) along the stream north-east of Prendwick. Mr. Anderson reports that junctions with the surrounding lavas are entirely hidden by screes. The rocks are steeply inclined greywackes and greyish-green laminated shales, unfossiliferous, but showing dendritic markings. They appear to be in every way comparable with the beds seen in the large Silurian inlier on the Border, to the west.

Cheviot Lavas and Granite.—As anticipated in last year's report, the similarity amongst the Cheviot andesites, and their extensive weathering, checks any attempt to map out individual flows systematically. Mr. Burnett believes that the most hopeful area for such work lies west of Kirknewton, where escarpments are numerous up to the Border; the petrography of the numerous rock-specimens collected is now in progress. The general inclination is south-east changing to south immediately east of the granite mass on Great Moor. The andesites are usually macroporphyritic, with xenoliths from adjacent flows; any trace of sediments is rare, though in a quarry ½ m. N. of Troughburn farm baked shale was seen. Ash-beds are uncommon, though sometimes tiny inclusions of such material can be noticed. Crush-lines and other evidences of dis-

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location are occasionally visible in stream sections, but are not easy to trace for any appreciable distance. Dyke-like fault breccias are seen at the foot of College Burn, and again in Common Burn, west of Wooler Moor: their directions are north and south, and east and west respectively.

Amongst the intrusions in the Kirknewton district, three main types can be distinguished, in addition to the tongues of granite fringing the main mass. These are (1) biotite-bearing pink porphyry, (2) non-biotite porphyry, and (3) the elvan class. The last-named trend N.–S., and are restricted to a narrow zone passing through Whitehall to Great Hetha. The first class, the most numerous of all, appear to radiate from a centre about ½ m. E. of Great Moor: the majority are dykes, sills having been noticed at only one locality, a quarry S.E. of Coldsmouth Hill. This sill is cut by a dyke of non-biotite porphyry, and it is possible that more such could be noted, if it were not for their similarity in colour to the surrounding lavas.

Mr. Anderson finds that the granite along the southern edge of the great central boss contains much ferro-magnesian material, with very little visible quartz. The rock varies in colour and grain, and also in the amounts of biotite and pyroxene. To the west of High Bleakhope a calcite-bearing fault breccia, from 20 to 30 yds. wide, marks the granite boundary. The lava-flows, as in Mr. Burnett's ground, cannot be mapped individually. Ash-beds are more conspicuous than to the north, and thick beds are seen near the head-waters of the Usway Burn and again to the west of Ingram. This latter bed, though in the main fine-grained and greyish-purple in colour, changes along the Breamish to a venetian-red agglomerate, almost wholly made up of angular hornfels fragments often 12 in. across. The porphyrite dykes in the granite all show phenocrysts of biotite, plagioclase and pink orthoclase. The majority trend north-west, though several are seen running at right angles to this direction in the Breamish above High Bleakhope.

Cementstones.—Mr. Anderson reports that the thick sandstones in this group continue towards Harbottle: one of them forms a prominent ridge followed by the Alnwinton-Netherton road, on both sides of which are extensive quarries. On the left bank of the Coquet, at the first bend above Sharperton bridge, is a 9-in. band of earthy limestone associated with green shales and thick cementstone bands: this is decalcified at the outcrop, and has yielded *Syringopora*, *Naiadites* and small gasteropods.

In the Alnwick district fine-grained and false-bedded sandstones, assigned to this group by Mr. Maden, are seen in the stream below the bridge three quarters of a mile N.E. of the Swinburne Arms.

Fell Sandstone.—Massive escarpments of this sandstone continue form any miles S.W. of Alnwick—Edlingham and Corbys Crags being particularly noticeable. Mr. Maden notes that cavernous patches are locally common, and weather-formed flutings are some-

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times seen on the crag faces. Slip-faults break the escarpment north-east of Edlingham and at Lemmington Bank Top. Farther south Mr. Fowler has examined the hilly ground east of Rothbury, where the crags north of the Coquet rise to the 700-ft. cortour. The basement beds are well seen at Thrum Mill, and there are many sections along the Rothbury-Morpeth railway. On Cragside estate old quarries and natural exposures abound, the crag-face S.E. of Tumbleton being fully 100 ft. high. Near Cragend farm there must be a large strike fault, for the Oxford Limestone is seen close by in the wood S.W. of Hope. Quite 600 ft. of strata must be cut out by this dislocation in spite of the known attenuation of the Scremerston Series in this district.

Scremerston Series.—Little work has been done on these beds in the past season. Mr. Anderson reports that the faulted outlier, seen at the foot of Long Crag east of Lorbottle Hall, is poorly exposed. The small bell-pit workings here were closed 30 years ago: they supplied coal for the kilns at Kiln House quarry, N.W. of Lorbottle.

Near Alnwick little new information has been got, for the old workings S.W. of the town have long been abandoned. Mr. Maden has examined the railway cutting between Townlaw Cairn and Moorgate, where three coals, none over 9 in. thick, are seen, along with a 6-in. limestone much veined with calcite. Other small sections can be seen in the stream below Stoop Hill, but they are much obscured by boulder-clay.

Middle Limestone Group.—To the south of Alnwick the Six-Yard, Eight-Yard and Great Limestones have all been quarried, and the valuable Shilbottle House Coal, lying between the Six-Yard (Acre) and Eelwell Limestones, is now being got from a 'drift' 300 yds. S.E. of the bridge carrying the North Road over the Hampeth Burn. Mr. Maden has mapped a new coal outcrop in this burn, 500 yds. west of the whin dyke. The seam lies about 300 ft. below the Eelwell Limestone, and shows two 6-in. leaves of good coal, separated by 2 ft. of fireclay.

Upper Limestone Group.—Exposures of this series S.E. of Alnwick are rarely seen. About 400 yds. N.N.E. of Hart Law an old pit, 66 ft. deep, wrought a 17-in. coal said to have the peacock lustre characteristic of the Hazon Lee Coal: it may possibly be the equivalent of the Chirm seam south of the Coquet.

In the Morpeth district, at Stanton House, 5 m. N.W. of the town, a quarry shows 16 ft. of limestone in beds, with shale above: latissimoid producti, with crinoid and shell debris, are seen. Mr. Fowler considers this to be the same as the limestone seen in the Font, 2 miles to the south, where the section is more extensive. The limestone in the river rests on massive sandstone, and there are fully 16 ft. of shales above; the stone shows 'cauda-galli' markings and is highly fossiliferous, resembling the Felton St. Mary's Limestone of the Coquet valley. At the head of Blagdon

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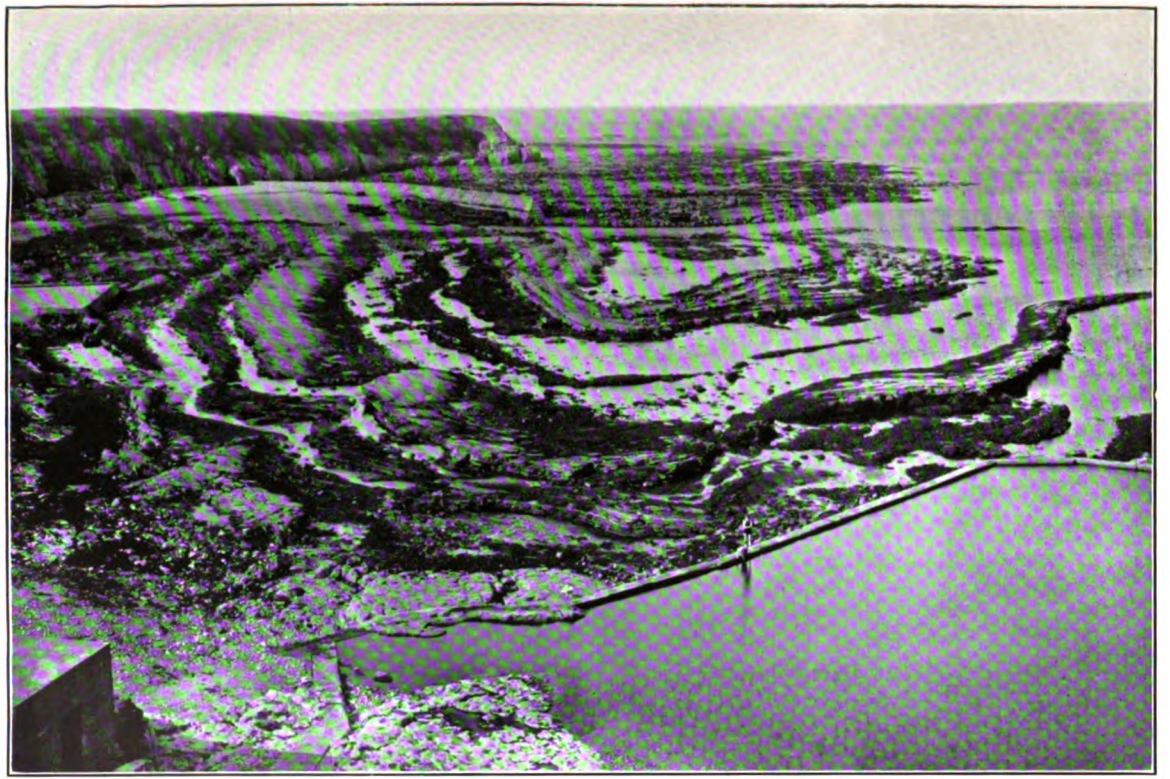

Syncline in Middle Limestone Group: Green's Haven, Berwick-on-Tweed.
[Taken from the Geological Survey memoir on 'Berwick-on-Tweed, Norham and Scremerston,' 1926.]

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Burn traces of a much higher limestone have been noted, probably equivalent to one of the two Foxton Limestones seen on the coast near Alnmouth.

Millstone Grit.—Several good sections in this group have been noted by Mr. Fowler in the Morpeth district. A typical example is seen in a disused quarry east of Cockle Park. About 18 ft. of rock can be seen here, the lower two-thirds very coarse, with quartzite, and more rarely, felspar pebbles up to 1½ in. across. Parts of the rock are disintegrated to a sand, and occasionally there are pockets of pebbles; lenticles of coal occur at intervals, along with calamite stems and indeterminable plant debris.

Coal Measures.—Much new information has been gathered in the belt of Coal Measures stretching southward from Morpeth to Warkworth. Although surface exposures are few and far between, many plans, pit and bore sections are available, for the ground is extensively mined. Hitherto, little or no attempt has been made to correlate the Broomhill area, at the north end of the field, with the Ashington-Woodhorn ground to the south. This has now been done by Mr. Fowler, so far as the higher seams are concerned, and his results are shown in the diagram (Fig. 7).

Steam coals prevail over the whole region, with the one exception of the Yard seam, an excellent house coal, in the Ashington field. No sure datum-line can be found, either in the coals themselves, in the sporadic 'shell-beds' of estuarine lamellibranchs sometimes noticed in the roofs, or in the intervening strata. Nevertheless the sequence can be followed from pit to pit, and there can be little doubt that the Radcliffe and Ashington Main Coals, each the thickest of their particular district, are one and the same: this conclusion is supported by the presence of a bedded sandstone, 50 or 60 fathoms above the coals. This sandstone, very probably the equivalent of the well-known 'Forty Fathom Post' of the Tyne, is over 70 ft. thick, grey-coloured, with reddish staining. At Woodhorn it is much quarried, and in part used for grindstones, as at Newcastle, while on the shore at Beacon Point the lower beds show pellets of red shale and pebbly bands. Mr. Maden also notes the occasional gritty nature of this sandstone farther north, between Cresswell and Seal Skears, and in the Broomhill field, near Hauxley, the pebbly bands and red shale pellets are again in evidence. Assuming that the Radcliffe and Ashington Main Coals are identical, the Top or Princess seam of the Broomhill-Newburgh field agrees with the Five-Quarter of Ashington. It is of interest to note, without stressing the fact unduly, that these latter coals all have a 'mussel-band' in the roof. Below them the Main Coal of Broomhill, a thick steam coal of first-class quality, agrees with the Low Main of Ashington, also a thick seam, and usually held to be the best steam coal in the county. Coals below this horizon are worked in both districts, but information regarding them is as yet insufficient for sound correlation.

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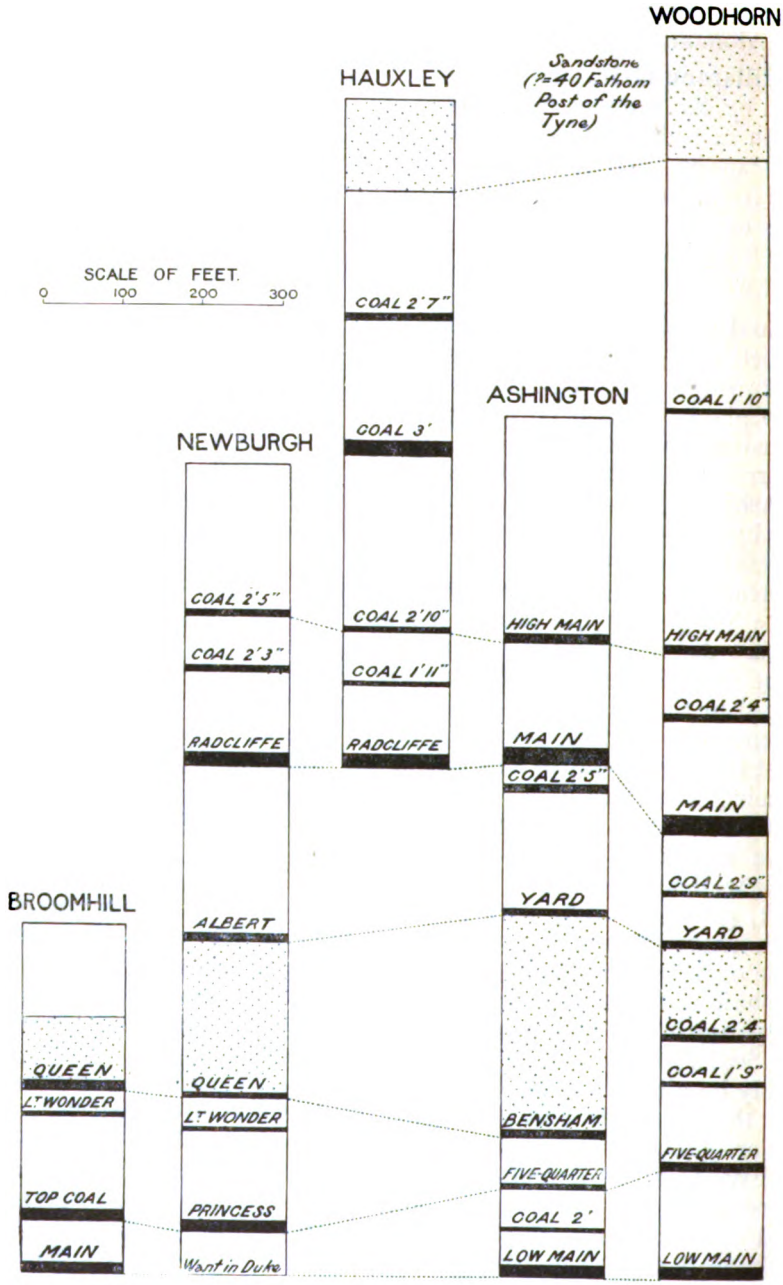

FIG. 7.—*Comparative vertical sections in the Coal Measures north of Morpeth.*

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The structure of both districts is much affected by faulting. In the Broomhill field the two chief dislocations run west by south. The largest, known as the Hauxley Fault, has a throw of about 130 fathoms, and one of its branches, down south-east 40 fathoms, limited the workings of the old Togston Pit alongside the Amble railway. The Bondicarr Fault, amounting to 75 fathoms immediately north of Newburgh Pit, lessens rapidly westwards, being only 16 fathoms at Broomhill, beyond which it seems to die out altogether. Whether it increases again is unknown; if not, there must be a series of small faults east of Coal Houses, as the outcrop of the Main Coal is shifted from west of Coal Houses to a short distance south of Togston, a displacement of a mile.

In the Ashington-Woodhorn district the chief faults also trend west by south, the largest being the Stakeford Dyke or Wansbeck Fault, down north, forming the southern limit of the workings. North of this is a parallel fault, amounting to 30 fathoms, down north, at Lynemouth Cottage and diminishing west. To the N.E. of Morpeth disturbances are severe, a perfect network of faults, mostly over 100 ft. throw, surrounding Longhirst Colliery. Others are known at Middle Linton (27 fathoms down north) and Ellington (22 fathoms down south-west). The latter fault is seen on the coast at Headagee, east of Cresswell Farm, the rocks in proximity being highly inclined.

Mr. Maden, working north of the Ashington field, on the north side of the Lyne valley, has traced one fault over three miles: this runs from East Stobswood past Northwood House to North Linton, throwing about 17 fathoms down south-west. Another dislocation, 22 fathoms down south, runs through the middle of Park and Grange Woods and probably passes out to sea at Druridge. Neither of these faults has been previously mapped.

Intrusions.—In the Rothbury district, Mr. Fowler has noted another exposure, a quarter of a mile further N.E., of the dyke S.E. of Tumbleton. This intrusion is in alignment with that at Tosson, 2 miles to the S.W. which it further resembles in weathering to a dark brown sand. Another dyke, only 4 ft. wide, is seen at Coal Houses, west of Mitford: this is of the more usual quartz-dolerite type.

An important dyke, hitherto unrecorded, has been mapped by Mr. Maden east of the Alnwick-Rothbury road, and 400 yds. south of Flamborough. This intrusion runs 10° N. of E. and is about 80 ft. wide; it is quarried by the County Council for road-metal, a 50-ft. face of whin being seen, with 30 ft. of drift on top. The rock is fine-grained and shows minute quartz-crystals plainly in a hand specimen. The full width has been removed and the walls of 'country-rock' exposed; yellow sandstone is seen on the south side of the quarry, while on the north side are 20 ft. of indurated blue-grey shale.

On the published map a dyke is shown crossing the Hampeth

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Burn 1,200 yds. west of the North Road. Mr. Maden notes that in a quarry on the left bank a band of sandstone with marine fossils, seen on the west wall, does not reappear on the east side, and the intrusion seems to be along a line of fault. Although high banks of dolerite appear on either side, nothing is seen in the stream itself, and the valley is probably pre-Glacial.

Farther upstream a new quarry has been opened in the Whin Sill at Hare Crag, half a mile south of Freemanshill. This working is used by the County Council for road-metal, and shows 15 ft. of dolerite free of drift or surface cover.

Glacial.—Several features due to late-Glacial drainage have been noticed during the past season. Mr. Anderson, working on the south side of the Cheviots, finds that the great cleugh of Fawdon Dene[1], which at one stage discharged its water into the Breamish valley, is associated with the impounding of the Biddlestone and Spartley Burns against the Cheviots. At a later stage in the retreat the waters overflowed into the Aln by way of the large 'dry valley' which runs from Scrainwood to Alnham. Obstruction of the waters of the Barrow Burn gave rise to a short, well-cut overflow channel half a mile S.W. of Alwinton, while another over the northern col of Cochrane Pike took the waters of Chesters Burn during the retreat of the Cheviot ice up the Breamish valley[2].

Mr. Maden reports that the long escarpment of the Fell Sandstone stretching from Alnwick to Rothbury is breached by a strongly marked overflow channel starting 300 yds. S. of Flamborough and running parallel with the Wooler-Morpeth road in a S.E. direction. This is known as Millstone Cleugh, and is fully 70 ft. deep. Apparently the stream debouched into a temporary lake, for beyond the exit Mr. Fowler noticed a stretch of flat ground with laminated clay seen at intervals: free drainage by way of the Swarland Burn was established when the ice-sheet left the Coquet valley above Felton.

Mr. Maden reports that the cut already noticed at Freeman's Gap, west of Alnwick, continues in a strongly marked valley passing under the Wooler branch railway towards Rugley Wood.

In the Lyne valley above Ulgham the streamlets running from Chevington Moor and Peigh Hills to join the River Lyne by way of Bailiff's Letch, all flow in broad shallow valleys apparently of glacial origin.

Gravels of various kinds have been noted in all the areas surveyed, but their origin is obscure. Mr. Maden mapped a line of gravelly hillocks nearly 3 miles long, stretching from Bank Top southwards to Glantlees Hill. They rise from 20 to 45 ft. above the surrounding country, and the mounds, which seem to be of clayey gravel, are strewn with sandstone boulders. They have also been noticed on the Simonside Fells and in both cases occur only on the dip slopes of Fell Sandstone areas.

[1] Smythe, J. A., *Trans. Nat. Hist. Soc. Northumberland, Durham, &c.*, vol. iv., 1909-1915, p. 108, and photograph No. 5.

[2] Smythe, *loc. cit.*, p. 108.

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Near Rothbury gravels have been mapped by Mr. Fowler up to the 500-ft. contour line, and others are seen east of the town on the Cragside estate, and again alongside the river at Holy Knowes.

West of Morpeth, along the Mitford-Hartburn road, is an irregular string of kame-like mounds elongated east and west, and known as Broomy Hills and Crawley Hills. These are made of coarse gravels in a clayey matrix and the presence of occasional 'kettle-holes' suggests an origin from a sheet of dead ice, in the last stages of the glaciation.

An excellent section showing the two boulder-clays so widespread in Northumberland is seen on the right bank of the Font at French Holm, west of Mitford. The sequence is:—

	Ft.	in.
Coarse gravel	—	
Reddish clay with boulders	2 to 6	0
Sand and gravel..	4	0
Very fine gravel	0	6
Blue boulder clay	30 to 60	0

R. G. CARRUTHERS.

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(B)—SCOTLAND

1. AYRSHIRE

E. B. Bailey, M.C., B.A., District Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc.
A. G. MacGregor, M.C., B.Sc. } Geologists.

THE revision of the South Ayrshire Coalfield has been practically completed by Mr. Simpson, who received every facility at the hands of the Dalmellington Iron Company. In adjacent areas of Sheet 14 Mr. Eyles has continued his mapping of the Lower Old Red Sandstone lavas and sediments south of Ayr, and Mr. MacGregor has dealt with Old Red Sandstone and Lower Carboniferous rocks near Straiton.

Lower Old Red Sandstone.—Between Maybole and Ayr the Lower Old Red Sandstone is divisible into a sedimentary group below, with lavas above. Mr. Eyles has furnished the following description. In the former, coarse purple micaceous sandstones are overlain by harder, thin-bedded, brown, green and grey felspathic and sometimes calcareous grits. Just below the lava flows, bands of hard yellow conglomerate are common.

The lavas themselves, for mapping purposes, fall into two classes distinguished by an absence or presence of porphyritic felspars. The former generally furnishes from one to three flows at the base of the series; while the latter constitutes by far the larger part of the Brown Carrick Hill area.

In Howmuir Quarry, 2 miles north-west of Maybole, at the extreme south of the main lava area, there is an interesting exposure of a flow with exceptionally fine spheroidal jointing, first noticed, apparently, by Sir A. Geikie. Three very large spheroids are seen in the quarry face, and one of them has a major diameter of approximately fifty feet. The lava itself is for the most part compact; but, at the extreme west end of the quarry, it becomes very amygdaloidal. It then presents perhaps the best example in the district of the infilling of a slaggy lava top with washed-in sandy sediments.

Spheroidal jointing of this magnitude is so rare that a few other examples may be cited for comparison. (1) An Old Red Sandstone lava in a roadside quarry near Sornhill farm, south of Galston, noted by Mr. E. B. Bailey. (2) A basalt somewhat tentatively interpreted as a sill by Mr. E. M. Anderson, associated with Millstone Grit lavas, near Rashillhouse farm, between Irvine and Stewarton. (3) A Calciferous Sandstone lava, examined by Mr. Bailey, at Machrihanish, Kintyre. (4) A Calciferous Sandstone lava, described by Mr. Martin and Dr. Tyrrell, near Bannockburn.[1]

[1] Martin, N., and G. W. Tyrrell, 'A Puddle-Trench Section at North Third, near Bannockburn,' *Trans. Geol. Soc. Glasgow*, vol. xiii, 1908, p. 243, and pl. xiii, fig. 2,

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At the east end of the main volcanic outcrop, Sheet 14 shows a tendency for the lavas to swing south-eastwards before they pass under more recent rocks in the neighbourhood of Dalrymple. It also shows detached outcrops of lava, 2 or 3 miles south of Dalrymple. In these Messrs. Eyles and MacGregor have found what appear to be the non-porphyritic basal lavas of the Brown Carrick Hills. Just as in the main area, these lavas are intercalated with sediments. Much of the igneous rock of the detached exposures belongs, however, to a pink 'felsitic' intrusion which can safely be taken as of Lower Old Red Sandstone age.

In the Straiton outcrop of Lower Old Red Sandstone, Mr. MacGregor finds a stratigraphical and volcanic sequence that agrees closely with that above described. Flaggy greenish felspathic sandstones are followed upwards by a conglomerate, and this is surmounted by a few flows of lava in which occur small olivines but no conspicuous phenocrysts of felspar; these basal flows are succeeded by a thicker development of lavas, in which felspar phenocrysts are generally fairly conspicuous. Pebbly or conglomeratic beds occur locally among the lavas, and fine-grained sediment has frequently penetrated into their cracks.

Upper Old Red Sandstone.—The unconformity at the base of the Upper Old Red Sandstone is one of the best marked features of the geology of Southern Scotland. Sheet 14 illustrates this feature clearly, when it is recollected that in it the Upper Old Red Sandstone has been grouped with the Calciferous Sandstone—into which it merges conformably. Allowing for the changes of nomenclature, one sees on Sheet 14 a geological depression reaching from Patna by way of Straiton and Crosshill to Dailly, and preserving along its course a considerable strip of Upper Old Red Sandstone and Carboniferous. This depression separates the Lower Old Red Sandstone of the Maybole and Brown Carrick area from that of Straiton. Furthermore, the Patna-Dailly post-Carboniferous depression seems to agree closely in position with a belt of post-Lower Old Red Sandstone upheaval. Thus the map shows Upper Old Red Sandstone resting directly upon Silurian near Straiton, and Mr. A. G. MacGregor has little doubt of the truth of this interpretation, although he has not been able to find actual junction exposures. A very important fault, separating Silurian and Lower Old Red Sandstone south of Straiton, and also marked folding of the Lower Old Red Sandstone south of this fault, are in all probability of pre-Upper Old Red Sandstone age.

Exposed unfaulted junctions of Upper Old Red Sandstone and older rocks are very rare in southern Ayrshire. It is, therefore, worth recording that Mr. MacGregor has found blocks of gritty sandstone enclosing 'felsitic' fragments near Ballochcoach Smithy, south of Dalrymple. At this locality Messrs. Eyles and MacGregor have shown the presence of a 'felsitic' intrusion of Lower Old Red Sandstone date, from which the 'felsitic' fragments are derived.

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The sandstone matrix is probably of Upper Old Red Sandstone age.

Carboniferous Limestone Series.—Mr. Simpson, who has revised a small area of limestone coals near Auldcraigoch, to the south-west of Dalmellington, furnishes the following report.

In the stream at Auldcraigoch, a coal has been worked to a small extent by the farmer. At the outcrop the seam is about 4 ft. thick, but varies and is greater in the workings.

The section seen is as follows:—

	Ft.
Fine white sandstone .. ..at least	10
Blaes and fireclay	10
Coal	4
Blaes	2
Parrot coal	1½
Fireclay, dark and with coal streaks	3
Dark blaes	1

The sandstone above the coal forms a well-defined scarp, and can be traced south-westwards for about half a mile, while the coal itself is exposed in one other section in a small stream 600 yds. south-west of Auldcraigoch.

The section above the thick coal agrees well with that at Keirs Castle, described by Mr. MacGregor[1]; and the coal no doubt represents the thick coal of Patna, or, at any rate, its top leaf.

Below the coal a considerable thickness of varied strata with some thin coals is exposed, and in two streams a sandy fossiliferous limestone is the lowest member of the Carboniferous Limestone Series seen.

Farther north, in Glenhead Glen, 400 yds. south-west of the Doon Bridge on the Dalmellington-Straiton road, two limestones, separated by 3 fms. of strata, are exposed. The published map, Sheet 14, shows the lower of these two beds, and apparently treats it as a member of the Lower Limestone Group. The limestone, however, contains typical *Productus latissimus* in large numbers, and certainly belongs to the Upper Limestone Group; it is probably the Index Limestone.

Millstone Grit.—Mr. Simpson has made a preliminary examination of a magnificent section of Millstone Grit strata exposed in Dunaskin Glen near Waterside, north-west of Dalmellington. From Corbie Craigs, where the Dalmellington Blackband Ironstone outcrops at the base of the Coal Measures, down to the Dunaskin Clay Pit, the strata can be followed practically uninterruptedly. From comparison with bores in the neighbourhood the exposure, totalling about 60 fms. of strata, represents the upper two-thirds of the Millstone Grit of this area.

In the varied succession of grits, blaes, fireclays and coals two thick posts of grit are prominent, and the lower of them is specially

[1] MacGregor, A. G., 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 93.

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interesting, in that it clearly exhibits a slight unconformity at its base. Where most complete, the section, showing the relations of the lower grit, reads as follows :—

	Ft.	in.
Coarse, false-bedded grit	42	0
Impersistent clayband ironstone	0	2
Bright coal	0	5
Blaes with sandstone plies	6	0
Coal	0	9

The amount of erosion varies, but, where it is greatest, about 6 ft. of strata are missing, and the coarse grit rests on the 9-in. coal.

It is interesting to note that the coal and clayband ironstone have resisted disintegration, whereas the blaes have disappeared completely. The ironstone was broken up and redeposited as an angular conglomerate with a sandstone matrix at and near the base of the grit. The coal, on the other hand, was apparently floated off in sheet-like masses, sometimes as much as 3 in. in thickness, sometimes only an eight of an inch or less. These rafts of coal now lie at all angles in the grit, which is undisturbed around them, indicating that little or no contraction of the coaly material took place after burial in the grit. In fact the coal must have been of much the same density then as it is now, though obviously less brittle and more leathery.

Coal Measures.—Mr. Simpson, during a detailed comparison of the bores through the Coal Measures of Central and South Ayrshire, has found that this part of the country is separated into two regions:—the more northerly has few or no coal seams above the Ell Coal, the more southerly has many.

The northern area is characterised by an entire absence of coal seams until 5 fms. above the Ell Coal. At this point a thin seam is usually met, and the predominant colour of the strata changes from red to grey. One passes from red sandstones and marls such as are typical of the Barren Red Measures to the more varied strata of the Productive Coal Measures.

The southern area carries coal seams for 70 fms. above the Ell Coal; and here also, with the appearance of coal, the Barren Red type of strata passes downwards into that of the grey Productive Measures. In these 70 fms. above the Ell there may be as many as eight coal seams ranging individually up to 2 ft. in thickness.

It will be seen from Fig. 8 that the northern area embraces the concealed coalfield of Central Ayrshire and extends north and south of it. We have few bores piercing the New Red Measures, but as similar conditions prevail north of Mauchline, at Barwheys, Mossbog, etc., as at Coylton, one may infer that they prevail also in the intervening area.

The southern area is developed in the New Cumnock and Dalmellington fields and extends northwards to Polquhairn and Skares. At Polquhairn it will be seen that the types are closely

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FIG. 8.

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adjacent. Here the change is strikingly abrupt. One passes from the full development of the southern area to that of the northern in less than half a mile.

It is probably significant that the boundary of the two areas coincides roughly with the disturbed belt known as the Steep Metals.[1] Where the southern type occurs north of this line it is always in a poorly developed form. Mr. Simpson's work on the Coal Measures thus follows in natural sequence Messrs. Eyles and MacGregor's observations published last year regarding the contrasted facies of the Millstone Grit and Carboniferous Limestone Series of Central and South Ayrshire.[2]

Volcanic Necks.—Many ash necks, presumably of New Red Sandstone age, are found in Ayrshire. In addition, there are a few necks, piercing comparatively old strata, regarding whose age there is more uncertainty. Here belongs the Heads of Ayr vent. Last year Mr. Eyles found blocks of curiously aggregated black calcite crystals in the ash of this neck; and this year Mr. Manson has succeeded in showing that these black crystals replace wood; and he has obtained several recognisable fragments of tree trunks in which the replacement has occurred without loss of the original form.

It is becoming probable that several of the New Red Sandstone necks pierce sills belonging to the teschenitic suite. It is hoped in the coming season to expose a junction in some chosen example.

Sills.—As regards their texture, the sills of South Ayrshire fall into two obvious divisions, monchiquitic and teschenitic; the significance of the division may be left open for the present. The monchiquitic sills, dykes and plugs of the district are so closely connected in character with the ash of the New Red Sandstone necks that there can be no doubt of their frequent time equivalence, especially as the intrusions and ashes often show significant association.

Recent work by Messrs. Eyles and MacGregor has afforded two new records of xenocrystal alkali felspars from monchiquite sills of the New Red Sandstone suite. It has also shown that similar felspar occurs in the ash of Greenan Castle, south of Ayr; in this last case the occurrence may be of Calciferous Sandstone date. The localities are as follows:—

Monchiquite sill, cutting Millstone Grit, Dunaskin Glen.
Monchiquite sill, cutting Cementstone Group, Meikleholm Burn.
Ash, perhaps interbedded in Cementstone Group, Greenan Castle.

None of these felspars has been sliced, but Mr. Eyles has determined mean refractive indices, approximately, in oil. Those of the first two are 1.530 and 1.531 respectively, which indicates anorthoclase. The felspar from Greenan Castle gives 1.535, which indicates a composition near albite.

[1] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 102.
[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 91–94.

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It seems that the alkali felspar xenocrysts, of the sills at any rate, should be regarded as deep-seated crystallizations proper to the enclosing monchiquitic magma.[1]

Most of the big sills of Ayrshire belong to the teschenitic suite, with teschenite, kylite, picrite, etc., as common types. Only in one instance has quartz-dolerite been recorded. In 1908 Mr. Boyle[2] showed that quartz-dolerite occurs in the Craigens sill-complex near Cumnock, and that this quartz-dolerite was associated with teschenite, which might be of later date.

The sill is intruded near the top of the Upper Limestone group and dips west with the associated sediments. Its section in its fullest development is as given in the index of Fig. 9.

(*a*) The top picrite is well exposed along a stream west of Craigens. Its base is not seen.

(*b*) Teschenite, below the picrite, is separated by thin baked sediment at the Craigens quarry from underlying, biotite-rich, olivine-dolerite. In the railway cutting, north of the bridge east of Craigens, teschenite, very probably the same sheet, overlies and chills against augite-dolerite belonging to (*d*) as was first recognized by Mr. Manson.

(*c*) Biotite-rich, olivine-dolerite, with purplish augite, and very ophitic, though fine-grained, rests without any contact-chilling on quartz-dolerite

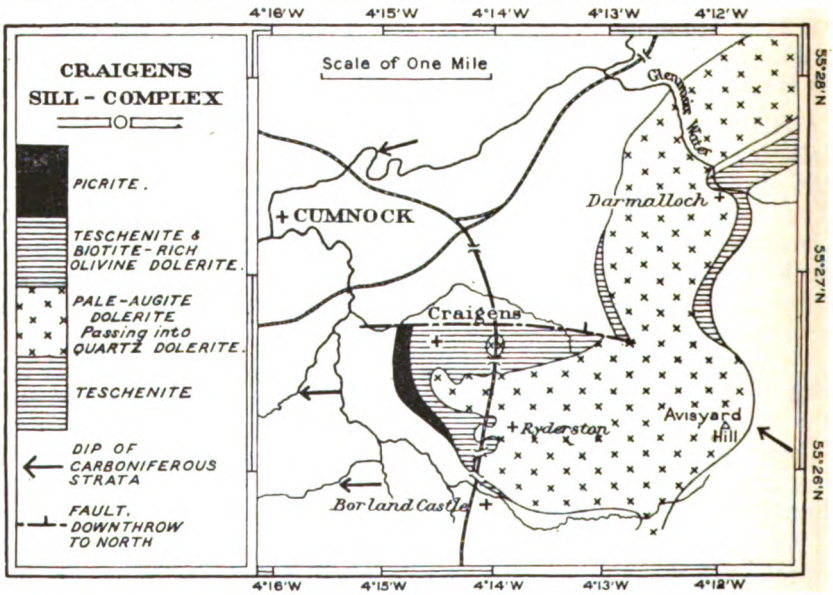

FIG. 9.

(*d*) north of the railway bridge near Ryderston. The same type of rock occurs in a very decomposed condition in the quarry at Craigens already mentioned. In fresh condition, it has also been collected north of the probable fault-line shown on Fig. 9.

[1] Eyles, V. A., 'Scottish Rocks with Anorthoclase Xenocrysts,' *Geol. Mag.*, vol. lxi, 1924, p. 471.

[2] Boyle, R., 'The Occurrence of Ultra-Basic Rocks in the Igneous Intrusions of the Lugar and Cumnock District,' *Trans. Geol. Soc. Glasgow*, vol. xiii, 1908, pp. 208, 209, 217, 219, 221.

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(*d*) The bulk of the complex consists of a dolerite with pale fawn augite, some olivine, and only very little biotite. It has undergone an unusual amount of juvenile change which has decomposed all the olivine and a very large proportion of the augite and felspar. Chlorite has been developed, and in many cases quartz in micrographic intergrowth with alkali felspar. The result is a quartz-dolerite of very different character from the common quartz-dolerite type of Central Scotland and the north of England. The micrographic quartz sometimes occurs in the heart of an early felspar as obvious 'quartz de corrosion.' The chlorite shows structures that recall the pseudo-organic appearance common in chlorophaeite. In fact, it is quite possible that it replaces this mineral, and that the main dolerite of the Craigens complex should be compared with the quartz-bearing olivine (fayalite)-tholeiite of Dalmahoy, at present under investigation by Dr. Campbell and Mr. Lunn.[1]

(*e*) Teschenite occurs near the base of the complex at Darmalloch farm. Mr. E. M. Anderson noted it cutting pale-augite dolerite (*d*) beside a little stream 400 yds. south of this farm.

To sum up, it is certain that, in this complex, typical teschenite cuts an abnormal type of quartz-dolerite. It is also clear that the latter is of approximately the same date as a biotite-rich olivine-dolerite of distinctly teschenitic facies.

Glacial Deposits.—Messrs. Eyles and Simpson have given close attention to the distribution of shelly boulder-clay in southern Ayrshire, with the result that Mr. John Smith's[2] observations have been strikingly confirmed. Fig. 10 shows the northern boundary of a sanctuary, including part of South Ayrshire, in which sea shells do not occur in the boulder-clay. North of this boundary sea shells are often abundant. Mr. Smith adopts the view that the sea shells are an indication of marine submergence. His hypothesis, however, has to face familiar difficulties. Two alone need be mentioned. In the first place, in their area of distribution the shells are found at almost any elevation from sea level up to 1,061 ft.; whereas within the sanctuary they are absent everywhere, even in extensive valley bottoms cut below the 600-ft. level. The second difficulty is illustrated in the condition of the strong and common shell *Cyprina islandica*: where this shell occurs in Ayrshire boulder-clay, it often retains epidermis but is almost invariably fractured.

Other significant features of the sanctuary are an absence of Highland erratics and a wide distribution of boulders derived from the Loch Doon Granite. These have led many glacialists, for instance the brothers Geikie, to recognise the Southern Upland sanctuary, and to ascribe its defence to an ice cap which, though of local origin, was confluent at its margins with the general ice sheet. The Highland ice current has been shown by these workers to have separated on approaching the sanctuary, and to have sent one branch to join the Irish Sea stream and another to run more or less along the Central Valley. The novel feature of Fig. 10 is the

[1] Campbell, R., and Lunn, J. W., 'Chlorophaeite in the dolerites (tholeiites) of Dalmahoy and Kaimes Hills, Edinburgh,' *Min. Mag.*, vol. xx, 1925, p. 435.

[2] Smith, J., 'The Drift or Glacial Deposits of Ayrshire,' *Trans. Geol. Soc. Glasgow*, vol. xi, 1898, supplement with map.

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suggestion that at one time the parting of the ways lay on what is now once more the floor of the sea. In most glacial maps, in agreement with evidence derived from striae and crags with tails, the divide is shown as lying well inland. There can be no doubt that such an inland position was maintained for a very long period. For instance, as Mr. Anderson points out, the crags of the Dundonald Hills, north of Ayr, have all their tails directed south-westwards towards the sea. The sea-floor position of the ice parting (Fig. 10) is conceived as having operated at a period earlier than the shaping of the Dundonald Hills. It is postulated primarily

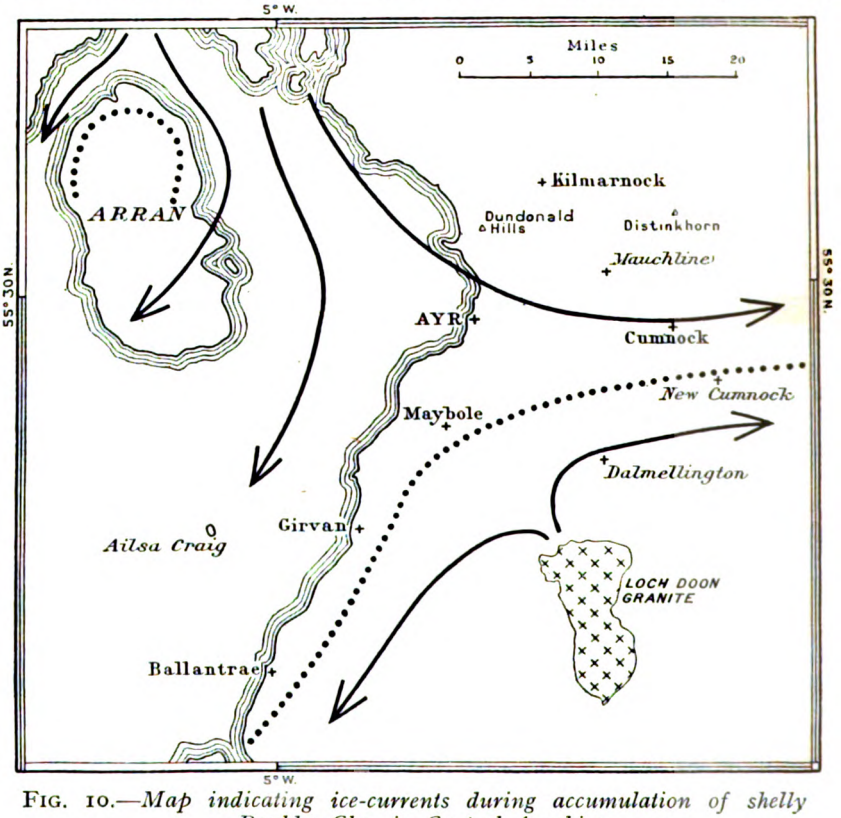

FIG. 10.—*Map indicating ice-currents during accumulation of shelly Boulder Clay in Central Ayrshire.*

to account for the wide distribution of shelly boulder-clay in Central Ayrshire. It receives strong support in Messrs. Simpson and Anderson's recent discovery of an eastward (as well as a westward) carry of Mauchline lavas and sandstone, and in Messrs. MacGregor and Richey's similar observations in regard to the Distinkhorn granite and hornfelsed sediments.

The outline of Arran glaciation furnished in Fig. 10 is based upon Mr. Gunn's[1] work in that island. E. B. BAILEY.

[1] Gunn, W., The Geology of North Arran, etc.', (*Mem. Geol Surv.*), 1903, pp. 133 134.

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2. LANARKSHIRE, AYRSHIRE AND PEEBLESSHIRE

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} Geologists.

THE re-survey of Sheet 23 (Lanark) has now been completed; a large part of the post-Silurian rocks of Sheet 24 (Peebles) has been remapped, and the revision of Sheet 15 (Sanquhar) has been continued. The work has been chiefly concerned with the older rocks bordering the coalfields, in order to complete for publication one-inch and six-inch maps.

The remapping of the Downtonian rocks of the Lesmahagow and Hagshaw Hill inliers, in the south-west part of Sheet 23 and in Sheet 15 adjoining, has been practically completed by Messrs. Anderson and Ross, together with Messrs. Richey, Phemister and A. G. MacGregor in the early part of the season. Mr. Ross has, in addition, completed the re-survey of the Carboniferous rocks on the east side of the Douglas Coalfield. Dr. Read has continued his mapping of Lower Old Red volcanic rocks and sediments in the Symington district (Sheet 23) north-eastwards to Biggar and Dolphinton (Sheet 24). The Upper Old Red Sandstone, and Calciferous Sandstone lavas and overlying sediments, that form the south-west end of the Pentland Hills (Sheet 24) and continue into Sheet 23, have been almost entirely revised by Mr. Phemister. The re-examination of the Carboniferous area near Carlops (Sheet 24) has been begun by Mr. Richey.

The completed mapping of the fluvio-glacial deposits in Sheet 23 and Sheet 22 adjoining makes it possible to trace a sequence of events in the waning of the Pleistocene ice-sheet. Mr. Phemister supplies an outline of his conclusions regarding the Glacial lake-deposits of the Newmilns-Strathaven valley, tributary to the main Clyde valley where Mr. Ross has been engaged.

Downtonian.—The Downtonian of the Lesmahagow and Hagshaw Hill inliers has been subdivided by Drs. Peach and Horne as follows[1]:—

(11) Chocolate-coloured sandstone.
(10) Conglomerate with large quartzite pebbles.
(9) Green and red mudstones with shales, etc.
(8) Red and yellow sandstones.
(7) Conglomerate with pebbles of Arenig volcanic rocks.

The above sequence is overlain by the Greywacke-conglomerate, which is taken as the basal member of the Lower Old Red Sandstone.

[1] 'The Silurian Rocks of Britain, vol. i, Scotland' (*Mem. Geol. Surv.*), 1899, p. 569.

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Some additions to our knowledge of the above groups are given below.

(*a*) A two-fold subdivision of Group (8) has been indicated by Dr. Peach in the memoir[1], and also on an unpublished manuscript map, and in the revision of the ground it has been found to persist throughout most of the Lesmahagow inlier. Mr. Anderson reports that as seen to the north and east of Middlefield Law, north-west of Muirkirk, the group consists of red sandstones and marls overlain by massive yellow or brownish sandstone, with occasional pebbles of quartz and chert. Further to the north-east Mr. Ross finds that the yellow sandstone forms an easily recognized zone outcropping with general north-westerly dip in the headwaters of the Dippal and Kip Burns, and again for nearly a mile along the Kype Water west of Dunside Reservoirs. At these localities the sandstones are more flaggy and less pebbly than elsewhere in the Lesmahagow inlier. The lower sub-group of red sandstones and marls occurs also in the Hagshaw Hill inlier, but there the massive yellow sandstone is not so distinct.

(*b*) In the area near Middlefield Law, mapped by Mr. Anderson, Group (9) consists of green, grey and brown, usually sandy shales, with thin bands of sandstone sometimes limy, and is well seen in the upper reach of the Slot Burn, where it includes the two fish bands referred to in the memoir[2]. Its total thickness is there at least 300 ft., but the mapping strongly suggests that it is laterally reduced by an unconformity at the base of the succeeding Quartzite-conglomerate. In the Wood Burn, 4 m. W. of Middlefield Law, similar shales have been noted by Mr. A. G. MacGregor. These have been searched for fish-remains without success, but they are succeeded by a conglomerate similar to a part of Group (10), and there seems no doubt that they represent Group (9). When traced along their outcrop these shales certainly vary in thickness, and at one point they apparently disappear.

(*c*) Mr. Anderson reports that in the Lesmahagow inlier the Quartzite-conglomerate, Group (10), is well seen in the Spindle Burn, a southern tributary of the Slot Burn near its source. Its lower part is there characterised by the usual large rounded pebbles of Highland quartzite, while its upper part contains instead many smaller and somewhat less regular pebbles of vein-quartz. Other constituents are fragments of jasper and chert, granite and fine-grained igneous rock, one or two of greywacke, and an occasional Highland grit. The group is here well over 100 ft., and may be several hundred feet in thickness. The same two-fold division of the group occurs also in the Logan Water. In the Hagshaw Hill inlier it is seen beside the upper reservoir near Glenbuck, where the base is obscured, and also in the Smithy Burn.

[1] 'The Silurian Rocks of Britain, vol. i, Scotland' (*Mem. Geol. Surv.*), 1899, p. 577.

[2] *Op. cit.*, pp. 578–9.

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At the head of the Powbrone Burn, south of Auchingilloch, Mr. Ross records a three-fold subdivision as follows:—

	Ft.
3. Massive pebbly red sandstone with sparse pebbles of quartzite and a greater proportion of vein-quartz pebbles up to 3 in. diameter, with intercalations of flaggy red sandstone..	200
2. Beds of rounded quartzite and granitic boulders up to 9 in. diameter	80
1. Pebbly sandstones alternating with flaggy red sandstone (base not seen)	40

The conglomerate already mentioned as found by Mr. A. G. MacGregor in the Wood Burn can be traced for a mile and a half to the north. It is thinner than most occurrences of the Quartzite-conglomerate, and its pebbles are almost entirely of vein-quartz.

(*d*) Mr. Anderson finds that the beds of Group (11) overlie the Slot Burn outcrop of the Quartzite-conglomerate, and extend in the direction of dip for about three miles to the west and south-west. The sandstones are mainly reddish in colour, sometimes marly, and often conspicuously false-bedded. The dip of about 20° is consistently away from the conglomerate, and although the great width of the outcrop is almost certainly in part the result of strike-faulting, the thickness of the group must be considerable.

Lower Old Red Sandstone.—Mr. Anderson reports that the Greywacke-conglomerate overlies Group (11) of the Downtonian beside the Greenock Water, about ½ m. N. of Greenockmains (Sheet 15). It contains many fragments of sandstone or greywacke, some of chert and jasper, and a few of vein-quartz. It is also seen overlying Downtonian sandstone near Nether Whitehaugh (Sheet 23). Close to the last locality, but on the downthrow side of a large fault, is a considerable thickness of volcanic tuff, overlain by lava-flows. These volcanic rocks must be of Lower Old Red Sandstone age, and the horizon is probably a considerable distance above the Greywacke-conglomerate. East of the Whitehaugh Water the unconformity at the base of the Upper Old Red Sandstone entirely cuts out the Lower. Where the latter is again seen to the north and south of the Glenbuck Carboniferous basin, the volcanic rocks are absent, and the formation as a whole is much reduced in thickness, consisting in places entirely of conglomerate.

Dr. Read has re-examined the lavas and associated sediments of Lower Old Red Sandstone age in the Biggar and Dolphinton districts of east Lanarkshire and north-west Peeblesshire (Sheet 24). These rocks form the north-eastern continuation of those of Symington mentioned in last year's 'Summary'[1]; the volcanic rocks are the central part of the belt grouped by Sir Archibald Geikie[2] in the Biggar Centre.

In the Biggar and Dolphinton districts the Lower Old Red Sandstone lavas and sediments occur in a belt, some four miles in

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 100.
[2] 'Ancient Volcanoes of Great Britain,' vol. i, 1897, pp. 325–329.

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width, lying between two north-east to south-west faults. One, the Southern Upland Fault, brings the belt of Lower Old Red Sandstone on the south-east side against rocks of the Southern Uplands. The other, to the north-west, termed the Walston or Pentland Fault, lets down Upper Old Red Sandstone and Calciferous Sandstone lavas against the Lower Old Red Sandstone.

The lavas comprise olivine-basalts, basic augite and hypersthene-andesites, acid hornblende-andesites and decomposed felsitic types which were originally trachytes and rhyolites. Basalts and basic andesites appear to be the dominant types; they are either dark, fine-grained and non-vesicular, or chocolate-purple, very vesicular and porphyritic. In only a few cases are the exposures good enough and the rock-types sufficiently distinctive to enable individual flows to be mapped, but, in one case, a very fresh hypersthene-andesite, bearing large crystals of hypersthene and felspar, and here called the Melbourne lava, has been followed from Edmonston north-eastwards for four miles to Dolphinton, and, in a second case, a very vesicular lava—the Howburn lava—which almost everywhere shows bedded sandstone in cavities, has been traced from Elsrickle to Dolphinton. Hornblende-andesites occur in thin inconstant flows at a few widely separated localities, as, ¾ m. E. of Hillside, Dolphinton; ½ m. S. of Whitecastle, Liberton; ⅜ m. S.W. of Hartree, Biggar. Trachytic and rhyolitic lavas are found in half a dozen masses. The largest of these, possibly made up of a number of small flows, forms Black Mount, Dolphinton, and is a grey-lilac felsitic rock showing in places a perfectly developed flow-structure. Other acid flows are seen at Quarry Braes, east of Biggarshiels Mains; Bizzyberry Hill, north of Biggar; Biggar Common, and above West Lindsaylands, Biggar. In general, the Old Red Sandstone lavas are thick flows which have no great breadth or length of outcrop. There appears to be no definite succession of types, for acid lavas occur at intervals throughout the pile.

Several narrow bands of sediment are found amongst the lavas, as, for example, at Elsrickle, between Shieldhill and Whitecastle, and around Culter and Symington. Such sedimentary intercalations consist of coarse felspathic sandstone and lava-conglomerate, the latter made up of rounded pebbles of the underlying lavas. A narrow belt of tuff and agglomerate appears at the southern foot of Bizzyberry Hill, Biggar. Felspathic sandstone and thick coarse lava-conglomerate form a belt from one to two miles wide from Blyth Muir, Dolphinton, southwards to Biggar. This belt holds many thin bands of ashy sandstones, whilst andesitic ashes are seen at many points towards its base near the Southern Upland Fault between Blyth Bridge and Kaimrig End.

The structure of the Lower Old Red Sandstone belt between Dolphinton and Biggar depends on three factors, (1) a general south-easterly dip over most of the area, modified by (2) a steep north-westerly dip adjacent to the Southern Upland Fault and (3)

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a marked thickening of the lavas from north to south. These factors produce a long narrow syncline, whose centre is occupied by the sandstone and lava-conglomerate already mentioned, with a gentle north-western limb and a steep or vertical south-eastern limb. The sediments intercalated in the lavas adjacent to the Walston Fault and the north-western part of the sandstones and conglomerates overlying the lavas show a general dip to south-east or east, but, on the south-eastern side of the syncline, lavas, ashes, sandstones and conglomerates are vertical for an average distance of half a mile from the Southern Upland Fault, as can be well seen at Muirburn, Netherurd and Blyth. Detailed mapping of the north-western boundary of the main sandstone and conglomerate against the underlying lavas establishes the third factor. North of Dolphinton these sediments are adjacent to the felsitic lava of the Black Mount—Mendick Hill ridge; farther south, at Dolphinton, the very vesicular Howburn lava and the Melbourne hypersthene-andesite intervene between the sandstones and the Black Mount felsite; west of Broomy Law the sandstone is still adjacent to the Melbourne lava, but many basic andesitic and basaltic flows are found between this lava and that of the Black Mount. South of Broomy Law the sandstones are in conjunction with basalts and basic andesites lying above the Melbourne lava, whilst still higher lavas—the rhyolites and trachytes of Bizzyberry Hill and Cambwell —come on towards Biggar. That is, to the north, the main sandstones lie on the Black Mount felsitic flows, whilst at Biggar dozens of acid and basic lavas occur between these two horizons and occupy three miles of ground, measured across the strike; the main sandstone and conglomerate overlap from north to south on to a rapidly thickening volcanic pile. This southerly thickening of the lavas, combined with the upturning adjacent to the Southern Upland Fault, results in the termination at Biggar of the main sandstones and conglomerates occupying the centre of the syncline, for, farther south, lavas build the whole four miles between the limiting faults. The extension of the mapping northwards from Dolphinton to West Linton will presumably establish the fingering-out of the Black Hill group of acid lavas into sandstones, until, in the Lyne Water, above West Linton, the volcanic group is represented by a few thin flows, and sediments occupy the whole area between the two faults[1].

Upper Old Red Sandstone.—On geological one-inch Sheet 24 (1868) a series of red sandstones forming the south-western end of the Pentland Hills is indicated as of Calciferous Sandstone age. Subsequently, scales of *Holoptychius* were found, and this year Mr. Phemister obtained a bluish waterworn scale, probably of *Holoptychius*, in one of the hard gritty bands of the series. These rocks were referred to the Upper Old Red Sandstone in a manuscript map made by Dr. Peach during the revision of the Silurian rocks of Southern Scotland. They consist

[1] Geikie, Sir Archibald, 'Ancient Volcanoes of Great Britain,' vol. i, 1897, p. 326.

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almost entirely of very porous, frequently somewhat incoherent, red sandstones containing hard gritty or conglomeratic bands. The cement of the sandstones and grits is calcite. At intervals red marls occur. These usually contain layers of nodular cornstone, and sometimes thin, highly inclined ribs of cornstone proceed from a higher cornstone layer down through about 8 ft. of marls to a lower cornstone band. Cornstones are not confined to any particular horizon in the series. In the South Medwin, 1¼ m. upstream from Medwinhead, the basal bed, resting unconformably on the Lower Old Red Sandstone lavas, is a massive very sandy cornstone.

Calciferous Sandstone Series.—Mr. Phemister finds that most of the basalts interpreted in the Old Series geological maps as intrusive and mapped discontinuously round the south-western end of the Pentland Hills are really extrusive (Sheets 23 and 24). The lava-flows form an almost continuous outcrop extending from Dunsyre on the south-east, south-westwards to Carnwath, and from there turning north and east along the north side of the Pentland Hills to Crosswoodhill. The lavas overlie the red sandstone series described above. No cementstones are known from this area, and there is no break in the lithology of the red sandstone series underneath the lavas. The latter are therefore taken to be the basal group of the Calciferous Sandstone Series. Volcanic vents filled by tuff and agglomerate have been mapped at Dunsyre and on the south peak of Bleak Law, 1½ m. N. of Dunsyre. The prominent hill known as Broomie Law, east of Dunsyre, is also built of tuff, but exposures are poor and it is not yet certain whether it should be mapped as interbedded tuff or as a vent.

In Gill Burn and its tributaries, 2 m. S.W. of Walston, the lavas are overlain by coarse grits and conglomerates of a whitish or greenish colour, quite different from the underlying red sandstones and grits. Succeeding dull green marly sandstones contain fish scales and plant fragments which indicate their Calciferous Sandstone age. Green sandstones and whitish and greenish grits continue to alternate until blue shales with marine Carboniferous fossils are found a short distance below a bridge, ¼ m. E.S.E. of Ogscastle. The thickness of strata between this point and the top of the lavas is at least 400 ft. but may be considerably greater.

Structurally the south-western part of the Pentland Hills consists of an anticline pitching to the south-west. As shown on the published geological map (Sheet 24), the Upper Old Red Sandstone, east of Medwinhead, extends unconformably across the outcrops of the Lower Old Red sediments and lavas. Farther south-west, inliers of Lower Old Red lavas, with occasional sediment and tuff, occur in the upper part of the South Medwin and again towards the source of the Westruther Burn. These inliers lie close to the axis of an anticline, from which the Upper Old Red sandstones dip approximately S.S.W. and N.N.W. The continuous outcrop of the succeeding Calciferous Sandstone lavas round the south-west

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end of the Pentland Hills establishes the south-westerly pitch of this anticline.

During the revision of the Midlothian Coalfield (Sheet 32), the mapping of the Carboniferous rocks, including the Oil-Shale Group, was extended southwards into Sheet 24 by Mr. L. W. Hinxman. This mapping is now being continued by Mr. Richey.

A basalt lava is intercalated in the Oil-Shale Group, which was recognised by Drs. Peach and Horne in the North Esk just north of Carlops, in Sheet 32[1]. It occurs below the only oil-shale of local importance, the Carlops Shale, which is probably the Dunnet Shale of the Straiton district[2]. This lava is a useful mark for the Carlops Shale in bores eastwards of Carlops. Near Macbiehill, 2 m. S.E. of Carlops, a bed of basalt outcrops, which is probably the same volcanic horizon. This was formerly mapped as a sill, and has been so regarded by Mr. Cuthbert Day, who has discovered the only known contact with overlying sediments in the Cairn Burn, 52 yds. above the Macbiehill-Deepsykehead road[3]. A re-examination of this contact last summer has added more evidence, and Mr. Day has also kindly lent microscopic slides of his material. The chief points which suggest that the bed is a lava, and not an intrusion are:—

(1) The basaltic material, which underlies a bed of sandstones, is soft and rotted, with a streaky appearance resembling the decomposed top of a lava. In its uppermost part sandstone occurs in thin layers clearly interlaminated with rotted basaltic material, and also contains water-rounded pellets of the latter. The circumstances may be explained by considering that contemporaneous rotting of the basalt took place, and that the material was subsequently rearranged by water and mixed with incoming sand.

(2) The rotted basaltic material is traversed by casts of roots, narrow cylinders of white fine sandstone, with the remains of the roots sometimes preserved at the margins as carbonaceous films. Similar casts also penetrate the overlying hard sandstone. The growth of roots down into the basalt strongly suggests that the latter is a lava-top rather than an intrusion. It may be added that the hardness of the overlying sandstone may well be due to the growth of vegetation upon it. It is a 'ganister' and not a baked sandstone.

On the other hand, a contact between basalt and sediment farther downstream, also observed by Mr. Day, is undoubtedly intrusive. Both basalts are of identical rock-type, but the last-mentioned is dyke-like. It may be a feeder to the lava that occurs at a higher horizon. It has certainly greatly baked its wall.

A limestone, a foot thick, which is correlated with the

[1] 'The Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 172.

[2] 'The Oil-Shales of the Lothians' (*Mem. Geol. Surv.*), 2nd edit., 1912, Plate II.

[3] Day, T. Cuthbert, 'Igneous Intrusive Phenomena at Upper Whitfield, near Macbiehill. . . .' *Trans. Geol. Soc. Edin.*, vol. xi, pt. 1, 1920, pp. 14–16.

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Cephalopod Limestone of the Amazondean Burn north-east of Carlops, is exposed in a stream east of Rutherford Mains. Its upper portion is a calmy, calcareous mudstone with cephalopods, and exactly resembles the Cephalopod Limestone, while its lower portion is a normal marine limestone with encrinites. This seam is higher than any oil-shale in the vicinity.

Carboniferous Limestone Series: Lower Limestone Group.—The sequence of limestones that outcrop between Carlops and Macbiehill (Sheet 24) can be correlated seam by seam with the well-known development of west Mid-Lothian (Sheet 32), though the total thickness of beds is less than half that of the Bilston Burn section[1] 10 miles to the north-east. During the mapping of the latter area the base of the Carboniferous Limestone Series was drawn at the base of the Gilmerton Limestone, while in the west of Scotland the base of the Hurlet Limestone was selected as a suitable datum-line[2]. Extensive researches of recent years suggest, however, the correlation of a thin limestone below the Gilmerton, the Abden of Mid-Lothian, with the Hurlet. In the first place, the Abden of Mid-Lothian was correlated by Mr. A. Macconochie[3] with the First Abden of Fife by means of a distinctive faunal sequence found below it. More recently, the same sequence, including a characteristic assemblage of lamellibranchs, was discovered by Professor P. Macnair[4] at the base of the Hurlet Limestone of the Glasgow district, and the identification of the Hurlet by these means has been further extended in the west of Scotland, by Mr. D. Tait[5] to the Carluke district, and by Mr. W. Manson[6] to North Ayrshire.

In the present revision of Sheet 24 it is therefore proposed to take the Abden Limestone as the base of the Carboniferous Limestone Series. This seam is exposed on the north and south sides of the Deepsyke, east of Upper Whitfield. In limy blaes below it Mr. Eckford has found some of the forms which are known to occur in the Abden fauna. A succeeding thick limestone, exposed in Whitfield quarries, is correlated with the Gilmerton Limestone. It is highly fossiliferous and largely composed of limy blaes. By these characters it may be locally distinguished from an overlying thick limestone well seen in Bents quarry, which is relatively solid and poor in fossils, pale-weathered and much jointed. The latter is correlated with the North Greens Limestone. Three limestones higher than the North Greens are exposed in the district. One, a

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[1] Macconochie, A., 'On the Geology of the Bilston Burn, near Loanhead,' *Proc. Geol. Assoc.*, vol. xxv, pt. 1, 1914, Pl. 6, p. 44.

[2] 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), 2nd edit., 1925, pp. 14–15.

[3] 'The Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 170.

[4] 'The Hurlet Sequence in North Ayrshire,' *Trans. Geol. Soc. Glasg.*, vol. xv, pt. ii, 1915, p. 239, footnote; and 'The Hurlet Sequence in the East of Scotland . . .' *Proc. Roy. Soc. Edin.*, vol. xxxvii, 1918, p. 194.

[5] 'The Economic Geology of the Central Coalfield of Scotland, Area IX' (*Mem. Geol. Surv.*), 1921, p. 28.

[6] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 124.

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5-ft. calmy limestone, almost unfossiliferous, is presumably one of the Vexhim Limestones. It is exposed succeeding the North Greens Limestone in a burn ¼ m. W. of Macbiehill railway station. Another seam, at least 15 ft. thick, calmy and fossiliferous, outcrops in the Cairn Burn ⅝ m. N.W. of Upper Whitfield. It is there faulted down against the North Greens Limestone, and adjacent bores show that it is to be correlated with the Bilston Burn Limestone. The topmost limestone, an irony impure band 1½ ft. thick, crowded with thin-walled shells, may be seen in the right bank of the Harlawmuir Burn, 500 yds. S.W. of Harlawmuir, and has been named the Harlaw Limestone by Mr. W. H. Laurie[1]. It corresponds to an identical seam exposed in the North Esk immediately below Newhall House[2], and may be correlated with a thin limestone overlying the Bilston Burn Limestone in the Bilston Burn[3].

Carboniferous Limestone Series: Limestone Coal and Upper Limestone Groups.—In the Douglas Basin Mr. Ross has been engaged in the collection of recent mining information, and in re-examining sections in the Upper Limestone Group on the east side of this coalfield. A fine exposure of the Gill Limestone and of the strata associated with it is seen in the Craig Burn above the point where it crosses the Lanark-Douglas road ¾ m. S.W. of Rigside. The details are:—

		Ft.	in.
	Faky blaes	4	0
	Gap .. about	12	0
	Blaes (mudstone) with small lamellibranchs	3	0
	Limestone rib with large productids	0	6
	Limy blaes, fossiliferous	9	0
	Blaes with ironstone balls	10	0
	Gap .. about	18	0
Gill or *Calmy Limestone*	Hard grey limestone bands up to 3 ft. thick, compact, sparingly fossiliferous, alternating with softer bands .. about	24	0
	Gap .. about	6	0
	Limy blaes, very fossiliferous	6	0
	Old workings in *Gill Coal*	7	0
	Fakes	5	0
	Coal or hard coaly blaes	0	10
	Fakes and dark faky blaes, with thin ironstone bands and balls, hard rooty sandstone near the top	12	9
	Fakes and sandstone with bands of faky blaes and with ironstone balls below	30	0
	Gap .. about	2	0
	Limestone rib, crinoidal	0	3
	Limy blaes	0	6
	Gap nearly	4	0
	Limestone band, very crinoidal	0	10
	Fakes and blaes with plant-remains, and with ironstone balls below	5	0
	Gap .. about	3	0
	Limestone, crinoidal, brownish, very hard	2	0

[1] 'History of Peeblesshire,' vol. i, 1925, Fig. 35, p. 319.
[2] Hinxman, L. W., *in* 'The Geology of the Neighbourhood of Edinburgh' (*Mem. Geol. Surv.*), 1910, p. 184.
[3] *Ibid.*

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The average dip is about 35° west. The Gill Limestone is correlated with the Calmy Limestone of the Central Coalfield but the *Edmondia punctatella* band[1] often found close below the limestone in other localities has not, up to the present, been noted in this section.

Glacial.—*Fluvio-glacial Deposits*: (1) *Newmilns-Strathaven Valley.*—Between Newmilns in Ayrshire and Strathaven in Lanarkshire, there is an extensive through-valley in which the rivers Irvine and Avon flow respectively west and north-east. These two river-systems are separated by a low watershed south-east of Loudoun Hill. In this through-valley and its tributaries, chief of which are the valleys of the Glengavel Water on the south and of the Glen Water on the north, occur great accumulations of sand and gravel. Professor J. Geikie[2] has indicated that these were deposited during the waning of the ice-sheet, those of the main valley being laid down in a lake. During the revision of one-inch Sheets 22 and 23 various officers have been concerned in the mapping of these deposits, and the information gained has been collated by Mr. J. Phemister, who gives the following summary of his conclusions.

The deposits and related phenomena, such as dry channels and terrace features, in the area represented in the accompanying sketch-map (Fig. 11) may be explained on the assumption that during the waning of the ice-sheet the ice first melted from the high ground leaving the main and tributary valleys filled with stagnant ice. The dead ice of the tributary valleys shrank, by melting, down into the main valley, and frequently left stranded rotting cakes beyond its margin. During the whole period of dissolution streams brought down sand and gravel from the hills, depositing their burden sometimes as flat terraces in lakes ponded against the ice, sometimes as moundy spreads between dwindling ice-cakes, sometimes as ordinary current-bedded deposits in free stream courses. When the ice had completely vanished the rivers cut their way through the fluvio-glacial deposits and re-sorted them into alluvial flats.

Mounds and ridges are found chiefly at the higher levels, and are therefore more especially characteristic of the earlier stages in the dissolution of the ice-sheet. Flat and rolling spreads in the main valley are later, and occupy the sites of lakes.

The main features of deposition in tributary valleys are best shown in the Glengavel Water and its tributary, the Powbrone Burn. Here, at the highest level, 1,000 ft., gravels were deposited among rotting ice-cakes and a flat terrace at about 950 ft. was formed in a small lake fed by the Powbrone Burn. As the ice shrank northwards down the Glengavel valley deposition of sand and gravel followed closely. In this way fluvio-glacial spreads, in some places very moundy owing to the presence of detached

[1] Haldane, D., 'Notes on the Discovery of *Edmondia punctatella* in Fife,' *Trans. Geol. Soc. Edin.*, vol. xi, pt. iii, 1925, Fig. 1, p. 388.

[2] 'The Great Ice Age,' 3rd edit., 1894, pp. 177–179, and pp. 189–190.

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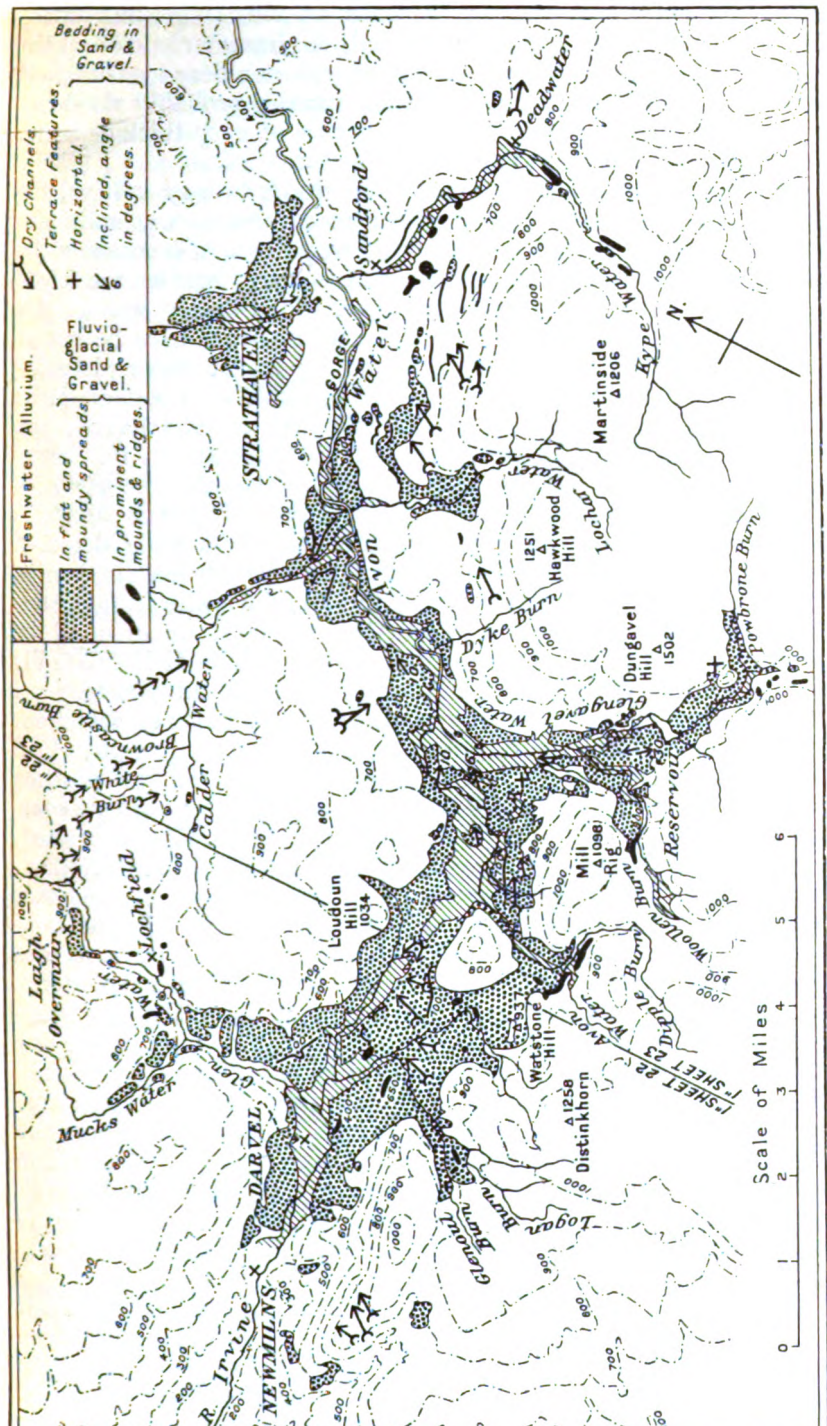

FIG. 11.—*Sketch map to show fluvio-glacial and alluvial deposits in the Newmilns-Strathaven valley.*

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ice-cakes during deposition, were built up with a general surface fall down the valley. This surface fall is characteristic of all the deposits in the tributary valleys. At the place where the Glengavel Water and Woollen Burn unite the ice margin probably stood fast for some time and permitted the deposition of very thick deposits, of which an 80-ft. section is seen.

After the ice had disappeared from the tributary valleys, the evidence shows that the ice in the through-valley was split into two lobes, one lobe continuous with western ice occupying the Kilmarnock platform, the other with eastern ice in the Clyde basin. The water which entered the through-valley was at this stage impounded to form a large lake whose level may be put at about 740 ft. This lake was dammed by ice at three places:— (i) across the narrow gap on the south flank of Loudoun Hill; (ii) across the Avon valley south and east of Strathaven, and (iii) across the broad shallow gap at Deadwater at 710 ft. Three main indications of the existence of this lake may be given:— (*a*) to the east of Deadwater a dry channel at 720 ft. leads eastwards down towards the Nethan valley, and Mr. Ross finds detached gravel deposits following in this direction and ultimately joining with the fluvio-glacial deposits of the Nethan valley; (*b*) delta-form spreads rising gradually to a little over 700 ft. occur in all the tributary valleys; (*c*) to the south-east of Loudoun Hill (Plate VI) there is a very extensive flat terrace at or about the 700-ft. level at its western end, but falling slightly in an easterly direction. To the west, the terrace ends abruptly in a bank 100 ft. high, which extends across the valley. This presumably marks the position of the ice front which was damming the Newmilns valley at this point, and against which the sand and gravel were deposited. As the ice shrank still farther eastwards into the main Nethan-Clyde valleys the Powmillon Burn at Strathaven continued to deposit sand and gravel down to a level of 500 ft. In the same way, at the west end of the through-valley the ice margin receded towards the main mass still occupying the low Kilmarnock platform. The lake waters impounded in the centre of the valley cut westwards into their own deposits, forming two channels which are now dry, and fed another lake whose existence is indicated by a small terrace at 600 ft. A halt of the ice margin near Darvel is considered to account for the terrace at 500 ft. which is found north-east and south-east of this place. Further shrinkage westwards allowed of the deposition, west of Darvel, of stoneless clays, sands and gravels at levels down to 350 ft. At this level the valley opens out on to the Kilmarnock platform and there the evidence of the ice-blockade ends.

The above is necessarily a mere outline of the fluvio-glacial history of the Newmilns-Strathaven valley, but two points more may be touched on. Kames are scarce. The best example is the ridge, three quarters of a mile long, known as the Kames of Avon. This ridge appears to have been formed in a crack in the upper

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Avon Water ice-lobe by deposition by water draining down the Dippal Burn. Prominent isolated mounds are common at high levels and are most easily explained as deposits in glacial lakelets[1]. Their generally earthy character is in agreement with this hypothesis.

(2) *Clyde Valley*.—In connection with the hydro-electric power works in process of construction at Bonnington and at Stonebyres Falls two interesting sections have been opened for tunnelling operations. The description given below is supplied by Mr. Ross.

The Bonnington section, on the right bank of the Clyde, almost

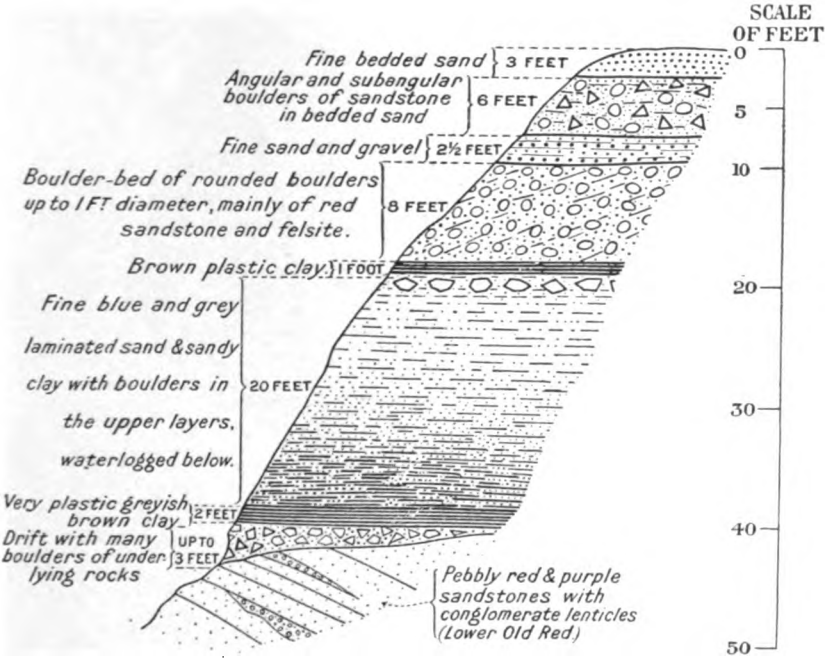
SCALE OF FEET
0
5
10
20
30
40
50
Fine bedded sand
3 FEET
Angular and subangular boulders of sandstone in bedded sand
6 FEET
Fine sand and gravel
2½ FEET
Boulder-bed of rounded boulders up to 1FT diameter, mainly of red sandstone and felsite.
8 FEET
Brown plastic clay
1 FOOT
Fine blue and grey laminated sand & sandy clay with boulders in the upper layers, waterlogged below.
20 FEET
Very plastic greyish brown clay
2 FEET
Drift with many boulders of under lying rocks
UP TO 3 FEET
Pebbly red & purple sandstones with conglomerate lenticles (Lower Old Red)

FIG. 12.—*Section at end of tunnel, Stonebyres Power Station, River Clyde.*

immediately to the east of Corra Linn and slightly above the 550-ft. contour, shows about 30 ft. of fluvio-glacial sand and gravel. The top 10 ft. or so consists of fine sand horizontally bedded, and the lower 20 ft. of steeply current-bedded lenticular layers of coarse gravel, shading along the bedding sometimes into finer gravel or sand. The general dip is northerly and the coarse layers are truncated above, the fine sandy layers appearing to overlie them unconformably. The material of the gravel is chiefly red sandstone, felsite and white sandstone, in the order of their relative amounts, and coaly layers occur both in the lower gravelly beds and in the upper sandy deposit.

The section at Stonebyres Falls (Fig. 12) is also on the right bank of the Clyde, at a point just below the 300–ft. contour to the

[1] Russell, I. C., *in U.S. Geol. Surv. 13th Ann. Rep.*, 1893, pt. ii, pp. 73–76.

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south-west of Nemphlar. The presence of large irregularly scattered boulders overlying the laminated sands and clays is possibly to be accounted for by the agency of floating ice in the waters of a temporary ice-blocked lake in which these sands were deposited. The upper brown plastic clay resembles in colour and texture the matrix of the red boulder-clay of the country to the south; and the overlying boulder-bed contains material typical of many gravel spreads presumably deposited by melt waters from Southern Uplands ice.

J. E. RICHEY.

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Glacial gravel terrace at 700-ft. level, Loudoun Hill, Ayrshire.

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3. FIFE AND KINROSS

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D. HALDANE, B.Sc.
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J. KNOX, B.Sc.

FURTHER progress was made during the year with the revision of the Fife coalfield lying in one-inch Sheet 40. Mr. Haldane was occupied mainly in the area south and south-west of Dunfermline, including the coast from Charlestown to Rosyth which comes into the adjoining Sheet 32. Later in the season he was stationed farther north, and revised the border of the coalfield between Saline and Rumbling Bridge. Mr. Allan was engaged on the ground to north and north-east of Aberdour and on the westerly extension of the Cowdenbeath field towards Lassodie and Halbeath. In the east Mr. Knox extended his re-survey of the Kirkcaldy area to Raith, Clunie, Thornton and Dysart. In addition to the coalfield revision, Mr. Allan made a detailed map of the superficial deposits in six-inch Sheet Fife 40 N.W. (north-west of Burntisland), this being one of the sheets chosen for special drift survey in co-operation with soil experts. Mr. Dinham was occupied with office work throughout the year, particularly with his contribution to the forthcoming memoir on Sheet 4 (Belford), England, and with the preparation for publication of the six-inch maps of the Stirlingshire coalfield lying in Sheet 39.

Old Red Sandstone.—A small area of this formation was revised by Mr. Haldane in connection with the coalfield north of Saline. It included some of the volcanic rocks which form the chief component of the Lower Old Red in this district, and are found mainly north of the great Ochil Fault and of its easterly continuation past Rumbling Bridge to Hardistown and Cleish.

The red and white sandstones of the Upper Old Red lie in a somewhat confused tract between the main Ochil Fault and the two important branches which leave it near Muckart and Hardistown respectively, meeting each other south of Cult Hill. These sandstones surround an inlier of Lower Old Red volcanic rocks at Monk's Grave, and cannot here be more than 500 ft. thick—which is at least 1,000 ft. less than they amount to in the West Lomond hills, 11 miles to east-north-east, and points to the very unconformable and uneven surface on which they lie[1]. Upwards, on the other hand, they pass with apparent conformity into the Cementstone Group, the base of the Carboniferous formation. At the junction a group of impure limestones, totalling 3 ft. 6 in. of limestone in 6 ft. of strata, was formerly wrought to some extent in the banks of the River Devon, north of Devonshaw. It has hitherto been

[1] 'Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, p. 37.

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supposed to be a cornstone, similar to that found on the hill slopes south and east of Loch Leven, where it is regarded as marking the top of the Upper Old Red Sandstone. But while the latter band is apparently of a type different from the impure (cement) limestones in the overlying Carboniferous[1], Mr. Haldane finds that the 'cornstone' of the River Devon is quite indistinguishable from the cementstones in the immediately succeeding strata; it will therefore be included with the Carboniferous sediments.

Calciferous Sandstone Series: Cementstone Group.—The best section of these beds, seen in the River Devon to the east of Muckart Mill, was revised by Mr. Haldane. About 150 ft. of strata are exposed and show, beside those mentioned in the preceding paragraph, over 32 horizons of cementstone in the form of thin bands or layers of nodules, 1 to 15 in. in thickness, alternating with red, green, and bluish clay marls, with occasional thin beds of calcareous sandstone. These sediments clearly belong to the Ballagan type, seen in the Campsie district. Another good section occurs a little farther east in the Caldron Linn of the River Devon: here basal beds again appear, but the top of the section is interrupted by a sill of dolerite. A third exposure is found 3 miles south-east from the above, on the north-west shoulder of Wether Hill, where an outcrop of cementstones and marls can be traced for half a mile.

This group, or at least the Ballagan type of sediment so well developed in the western part of the Central Valley, dies out towards the north-east, and the exposures above described are perhaps its farthest representatives in this direction. Of the 60 or 70 ft. of strata found between the base of the Carboniferous Limestone and the Upper Old Red Sandstone on the slopes of the West Lomond hills east of Loch Leven, not more than a foot or two at the base have been supposed to be of Ballagan character—a point requiring further investigation: the remainder is apparently a representative of the highest beds of the Oil Shale Group, since it passes conformably upwards into the Carboniferous Limestone Series. The volcanic zone, usually regarded as belonging to the Cementstone Group, is already absent here, its last trace being found east of Navity Hill on the south side of the loch[2]. The Oil Shale Group, on the other hand, is poorly developed in the west of Scotland, where it is at least in part represented by a period of unconformity with overlap, and is locally entirely absent; but it thickens rapidly to north-east and along the northern margin of the Fife coalfield appears to rest on the Upper Old Red Sandstone, replacing the Cementstone Group, which has never been definitely recognised in the county beyond the Lomond Hills[3]. The relations of the groups in this area of replacement are not certainly known, but it is possible

[1] *Ibid.*, p. 36.
[2] 'Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, pp. 43, 44.
[3] 'Geology of Eastern Fife' (*Mem. Geol. Surv.*), 1902, pp. 70, 76.

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that the bulk of the sediments of both groups is absent by unconformity within the series, combined with overlap, leaving only higher Oil Shale and lower Cementstone strata between the Carboniferous Limestone and the Old Red. Intra-serial unconformity, at least, is proved in the Georgetown Burn south-east of Hardistown, where sandstones belonging to an unknown horizon in the upper group rest on a denuded surface of the volcanic zone, and contain pebbles of its lavas in their basal beds.

Calciferous Sandstone Series: Oil Shale Group.—As mentioned above, this group is poorly represented in the west of the Central Valley. Of the eponymous shales so well developed in Mid and West Lothian the highest seams alone occur, and they only in one district, near Strathaven west of Lanark; elsewhere the group consists of sandstones, marls and occasional coals with a few marine limestones or shell-beds—precursors of the Carboniferous Limestone Series—like those which mark the top of the group in its typical Lothian development. Such is the case in the Bannock Burn near Stirling, where these strata are first known to the west of Fife. In the area around Muckart Mr. Haldane finds that this group never appears at the surface, but its existence in depth below the adjoining coalfield is probable, since sandstones of this age are found in the Georgetown Burn already referred to, and in an inlier to the west of Loch Fitty. As suggested above, the lower strata of the group are probably absent here from overlap.

Farther south, this division occupies a considerable part of the coast, and is separated only by 2 or 3 miles from the shale-fields of Hopetown and Dalmeny. The typical oil-shale sequence is accordingly to be expected, with decreasing overlap at the base—subject possibly to north-westerly attenuation in the lower portion with deterioration of the shales themselves, such as was found in bores near Blackness[1]. The sequence has, however, not yet been proved here, and the horizons of the more important shales are cut out of the coast section by the large Inverkeithing Fault, running from Rosyth to Aberdour, with a northerly downthrow.

On the south side of this dislocation the structure shows a succession of anticlines and synclines of various depths, oriented along axes running north by east, and is thus a repetition of that which obtains on the opposite shore of the Forth estuary. A large area is concealed beneath the Rosyth Naval Base, but much information was obtained at the time of construction, and the section then found by Mr. R. G. Carruthers[2] belonging to the neighbourhood of the Burdiehouse Limestone, may be put on record (Fig. 13). It will be seen that the Camps Shale is represented, and certain 'gas blows' which occasioned much trouble during construction of the basins were ascribed by Mr. Carruthers to the distillation of this and other shale seams by the intrusive dolerites seen at Rosyth Castle and

[1] Lee, G. W., in 'Summary of Progress' for 1919 (*Mem. Geol. Surv.*), 1920, pp. 57–61.

[2] 'Summary of Progress' for 1913 (*Mem. Geol. Surv.*), 1914, p. 102.

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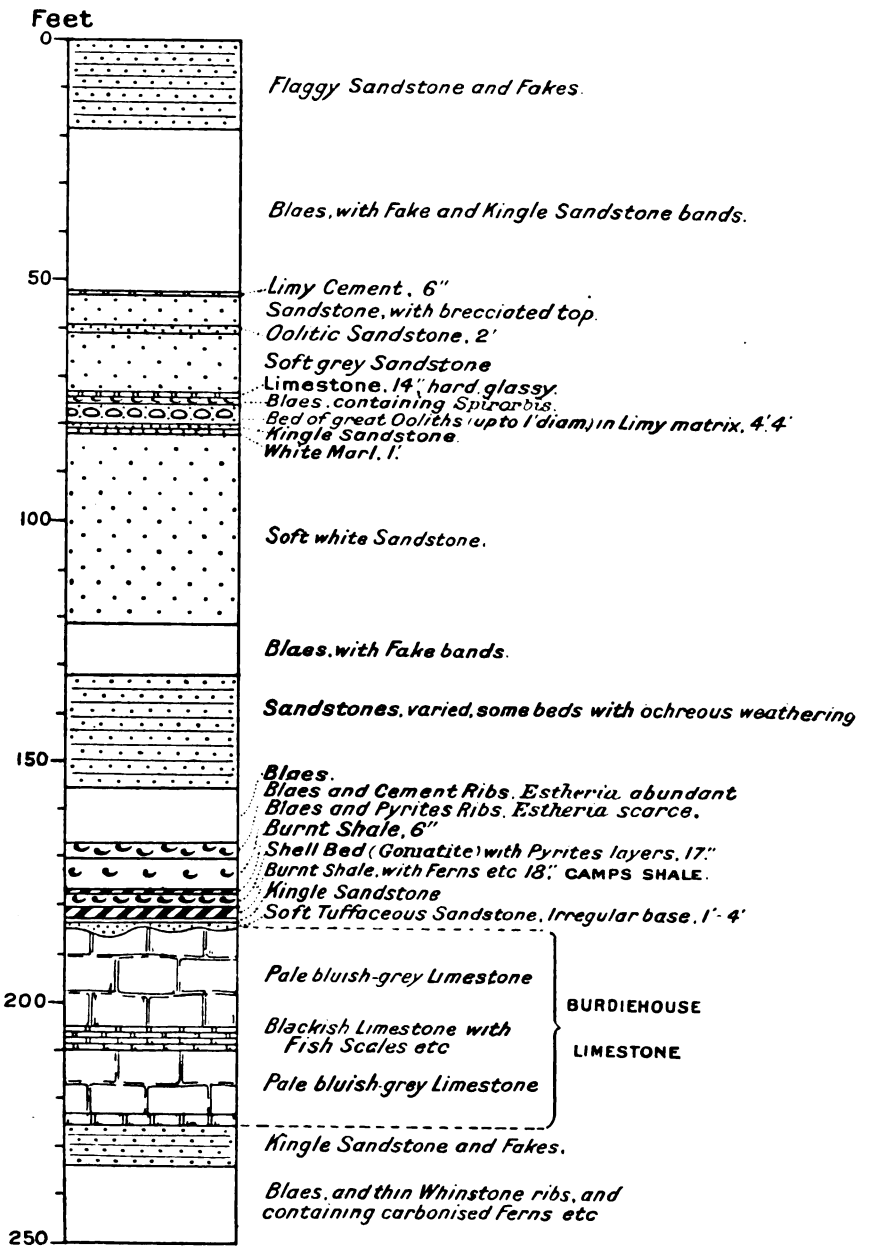

FIG. 13.—*Section of part of the Oil Shale Group, measured in the excavations for Rosyth Docks, 1913.*

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Du Craig. Eastwards from Rosyth, the coast line from St. Davids Harbour to Aberdour has been examined in detail by Mr. Allan; the only bed outcropping whose position in the typical shale-field sequence is known remains, however, the Raeburn Shell Bed of Seafield, St. Davids, and of the Fordel Mineral Railway cutting[1]. This being high in the succession, the Broxburn and Dunnet shales should be present in this area, but the occurrence of the ash of St. Davids, probably a bedded deposit at a lower horizon, and the comparative frequency of dolerite sills, suggest that the shales may prove to be of poor quality.

On the north side of the Inverkeithing Fault, the higher shales at least should occur between Rosyth and Dunfermline. No solid rock is seen in this obscure tract other than a few exposures of sandstone, but it is hoped that fuller knowledge of the structure may be obtained in the near future from the drainage tunnel now in course of construction across this area and examined from time to time by Mr. Haldane.

In the ground north of Burntisland further revision work has been done by Mr. Allan and Mr. Knox. West of the Binn the former has obtained more detailed records of the succession in the neighbourhood of the Burdiehouse Limestone, showing that the strata consist almost entirely of sandstone for 25 fms. below that seam, and are predominantly arenaceous for 15 fms. above the blaes resting on the Dunnet Shale. It seems, further, that the ochreous limestone intercalated with tuff, formerly wrought west of Binnhead, is about 370 ft. above the Dunnet Shale and thus on the same horizon as the limestone of Binnend old school, the supposed equivalent of the Fells Limestone of the Lothians[2]; probably the limestone at Silverbarton is the same band repeated by a fault. Considerable modification of the existing maps has been found necessary as regards the boundaries of the lavas and tuffs.

East of Burntisland the plant-bearing limestone near King Alexander's Crag, first reported in last year's 'Summary of Progress,'[3] has been excavated to a depth of 18 ft. without reaching its base. Mr. Knox finds that it maintains a fairly uniform character throughout, though the lowest visible foot or two is rather more carbonaceous than the rest.

Carboniferous Limestone Series: Lower Limestone Group.—Excavations were made at two of the overgrown quarries near Parkend, 4½ miles east of Dunfermline, in an endeavour to ascertain more about the characters of the limestones along the western border of the Burntisland anticline. In the quarry east of the steading the section exposed was:—

	Ft.	in.
Hard calcareous blaes	7	0
Shelly blaes	0	4
Limestone, grey, crinoidal	7	6

[1] 'The Oil-Shales of the Lothians' (*Mem. Geol. Surv.*), 2nd edit., 1912, pp. 82, 83.
[2] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 108.
[3] *Ibid.*, p. 109.

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The full thickness of the limestone was not bared but it cannot be much greater than the above figure, strata which must lie immediately beneath being seen just to the rise of the quarry. The predominant fossil in the calcareous blaes is *Productus longispinus*, as in the lithologically similar beds at Bucklyvie quarry to the north. The excavation in the other quarry, north of Parkend steading, showed :—

	Ft.	in.
Dark limy blaes, with large lenticular ironstone nodules and small fossils throughout	26	0
Limestone, impure false-bedded crinoidal	0	8
Limestone, grey crinoidal (bottom not reached)	5	6

Here the overlying blaes included *Ambocoelia urei*, large *Posidonomya corrugata*, and abundant *Dentalium*.

These excavations by Mr. Allan and Mr. Tait prove definitely that the quarries are in different seams—a conclusion in agreement with the old mapping but hitherto uncertain because of the possibility of faulting by one of the transverse faults so abundant in the Dunfermline Splint Coal of the adjoining coalfield. The section north of Parkend compares well with the Charlestown Main Limestone and its associated strata, and is probably to be correlated with that seam, though definite proof has not yet been obtained. The seams wrought in the east quarry and at Bucklyvie, both underlain by blaes containing a coal seam, are taken to be the Charlestown Station Limestone, the probable equivalent of the Hurlet of the west of Scotland.

Two thin limestones seen in the stream west of Parkend are probably the Upper and Mid Kinninny seams, but this point is still uncertain.

Mr. Haldane has re-examined the coast from Limekilns to Crombie Point, where excavations for the magazines of the Explosives Depot have yielded some good sections; but the structure is much obscured by abundant minor faulting.

Carboniferous Limestone Series : Limestone Coal Group.—The area between Dunfermline and Torryburn, revised by Mr. Haldane, contains old workings in the Dunfermline Splint and Five Foot Coals, of which little or no information can now be obtained.

Mr. Allan has continued his careful revision of the important mining district around Cowdenbeath, and finds that considerable alteration of the existing mapping will be necessary. The greater part of his results must await publication in the new maps and memoirs of the Fife coalfield, but one example may be given here. To the west of Loch Gelly a large fault with downthrow to north was known to pass south of Newton, and believed to take an east-south-east direction; this is now found to run east by north, and to consist of two branches diverging eastwards before they cross the loch; while the fault shown on the one-inch map as 50 to 100 fms. down to north proves to coincide with a fault of 48 to 50 fms. throwing in the opposite direction.

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Carboniferous Limestone Series: Upper Limestone Group.—Further progress has been made by Mr. Allan in following the outcrop of the Index Limestone in the area south and south-east of Loch Fitty, where it is let down by a large fault or series of faults running along the loch. North of Kirkcaldy Mr. Knox has detected an exposure of limy blaes in the glen about half a mile south-east of Dunnikier House. Dr. Lee reports that the assemblage of fossils collected at this point contains nothing diagnostic, and is rather more rich than is common at the Index Limestone in Fife. It appears from mining evidence that the blaes lie about 50 fms. above the Index, and so correspond to a well-marked limy horizon occurring at about this position in bores further to the north.

Millstone Grit and Coal Measures.—Mr. Knox has obtained additional bores and pit sections, and has re-examined the coast section from Pathhead to Blair Point. This new information will introduce some minor alterations into the mapping of the Dysart coalfield, but it is probable that in the main the old map will require little modification.

Igneous Rocks.—The lavas and ashes of the Calciferous Sandstone of West Fife, examined by Mr. Haldane, have been referred to in a previous paragraph. Those outcropping in the Burntisland anticline have been further investigated during the year by Messrs. Allan and Knox. Mr. Allan has been occupied with the complicated country west of the Binn, and has found reason to make numerous alterations in the details of the existing mapping. Farther east, Mr. Knox has found several small areas of ash and agglomerate which appear to mark the position of vents hitherto unrecognised; in one case the evidence seems to be fairly definite—at Stoneyhall Hill, 2 miles north of Burntisland. The appearance of this hill as viewed from the west is very suggestive of a vent, and inspection shows that its summit is composed of fresh dark basalt, while a belt of coarse ash and agglomerate can be traced for some distance around its northern and western slopes.

Proof of volcanic activity near Lochore during the deposition of the upper seams of the Limestone Coal Group was brought forward by Mr. Allan in last year's 'Summary,' and this year Mr. Knox, from a study of bore journals courteously supplied by the Fife Coal Company, has derived evidence of similar activity on the foreshore at Kirkcaldy. A bore put down 300 to 400 yds. south of Kirkcaldy Harbour started in sediments about 15 fms. thick, with the position of the Index Limestone at the top; it then entered ash, and continued in the same material until boring was stopped at a depth of 48 fms. below this position. Six hundred yards farther south, another bore started in 20 fms. of ash, the base of which was found, by continuing the bore into the underlying sediments, to rest on a horizon about 20 fms. below the same position[1]. A

[1] This bore is close to the gasometer, and shows that the tuff there reported ['Geology of Central and Western Fife' (*Mem. Geol. Surv.*), 1900, p. 165, footnote] is not lying in a neck, but forms part of a bedded ash resting on a normal section of sandstones, coals, etc.

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third bore, close to the harbour, found 3 fms. of ash intercalated in the sediments just beneath the Index Limestone position, but below this the normal sequence of strata was proved to a depth of 120 fms. These data point to the presence of a volcanic vent on the site of the first bore, and indicate that while all but the latest discharges of ash were being carried south (and perhaps also to east), normal sedimentation was taking place to the north close up to the vent, and that all activity had ceased shortly before the deposition of the Index Limestone.

The intrusive sills, both of teschenite and of quartz-dolerite, play a conspicuous and important part among the rocks of the Fife coalfield, but in those places where the strata are most thoroughly proved by boring the regularities frequently exhibited by the sills are found to be liable to such abrupt changes that no short account can well be given of their behaviour. In areas where the structure is less well known, as, for example, the country around Loch Glow, their position in the sequence may prove to be impossible of explanation in any general terms. The details, however, so far as ascertainable, will be shown on the six-inch maps and described in a future memoir, after the completion of the petrological examination.

Glacial.—The easterly movement of the ice during the later stages of the Glacial Period is well shown in the parallel drumlins and ridges which characterise the surface of the ground in the western part of the county. Flow in the same direction took place also at an earlier period, before the deposition of the drift cover, when the ice was still scouring the underlying rocks. Mr. Haldane has observed some interesting indications of this earlier scour which are quite independent of the surface features. Thus the Dunfermline drainage tunnel now constructing is found to cross clay-filled hollows in the rock which correspond in no way to the hollows in the superficial drift. A neat example has also been exposed recently at Crooks Quarry, Inverkeithing, and is illustrated in Plate VII. It takes the form of a groove in the quartz-dolerite sill, 20 ft. in breadth, with an exposed length of 150 ft. and a minimum depth of 10 or 12 ft. This channel is filled with stiff blue boulder-clay, now in process of removal, and made no feature at the original surface of the ground. The sides, which are steep, in places vertical, are finely striated, showing that the groove was occupied by moving ice before it became filled up with the later deposits of the same glacier.

C. H. DINHAM.

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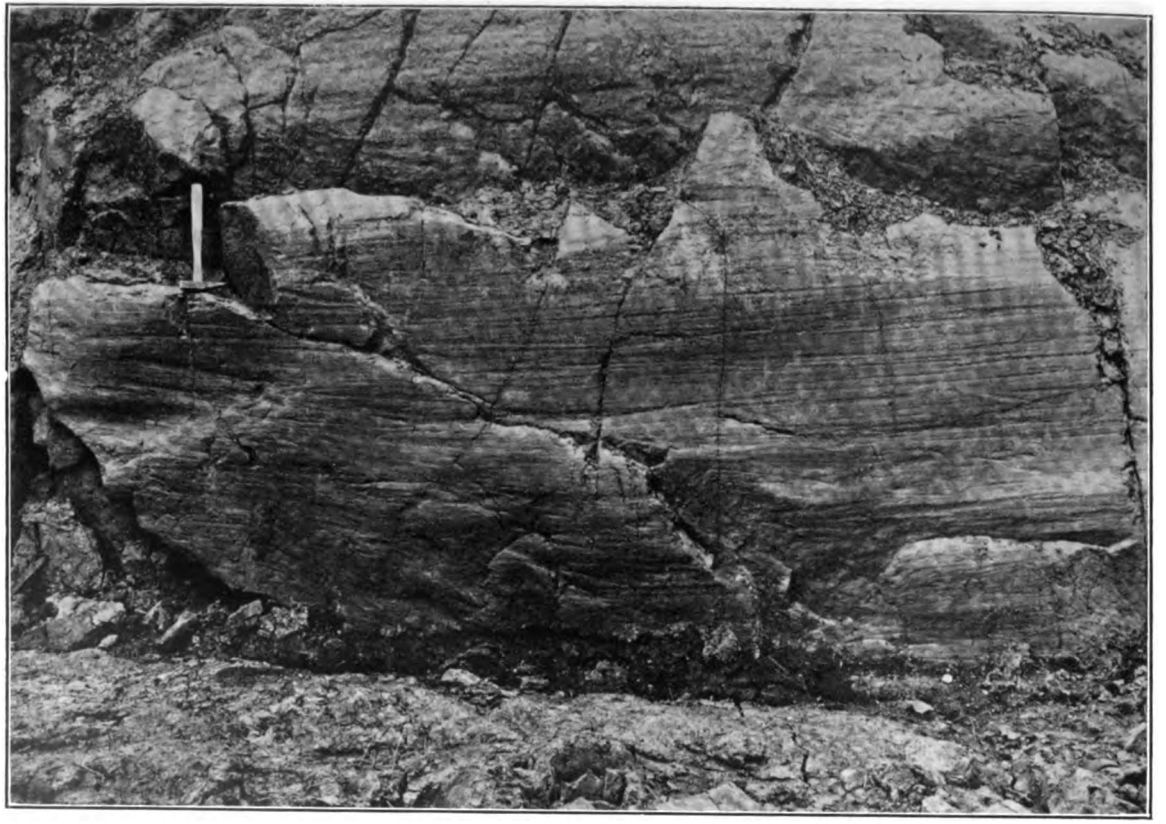

Striae on north side of glaciated channel in dolerite, Crooks Quarry, Inverkeithing, Fife.

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III.—PETROGRAPHICAL WORK

1. England and Wales

In addition to the current petrological work connected with the areas now being surveyed such as Cumberland, the western Midlands and Northumberland, Dr. Thomas investigated with Mr. Pocock an extensive outcrop of basalt that occurs to the south and west of Wellington, Salop. From its columnar structure and general massive appearance, it has hitherto been regarded as a sill; but, Mr. Pocock has shown by detailed mapping that the mass is in no way transgressive, and the petrographical characters are such as definitely prove its extrusive nature. The mass has been made the subject of an Appendix to the present volume (p. 140).

2. Scotland

Dr. Thomas has been engaged on the petrology of the Tertiary igneous rocks of Ardnamurchan and together with Mr. Richey re-visited the ground in order to reconsider some of the evidence, more particularly that relative to the ages of individual intrusions.

The order of the main events that took place during the period of igneous activity in Ardnamurchan, as far as these can be ascertained, is as follows:—

(1) The eruption of Plateau Basalt Lavas.

(2) The formation of volcanic vents and their infilling with agglomerate. The material of the agglomerate consists largely of rhyolite, trachyte, and big-felspar basalt as well as brecciated country-rock. These vents include (*a*) the Ben Hiant vents, and (*b*) vents disposed around Meall Meadhoin. The central and western of the latter series of vents are largely obliterated by later intrusions.

(3) A series of intrusions associated with the two groups of vents specified above. These intrusions are of quartz-dolerite with some granophyre and may all be later than the vent-agglomerates. Ben Hiant, etc.

(4) Intrusion of quartz-dolerite as cone-sheets, mainly referable to a centre at Aodann, 3 miles W.S.W. of Meall Meadhoin.

(5) Formation of the Earlier Ring-Dykes around the Aodann centre. During this period cone-sheets were intruded which traversed some of the ring-dykes, but are earlier than others. Vents were also formed, as shown by the linear vent of Glas Eilean which runs parallel to, but brecciates the Earlier Cone-Sheets.

(6) Intrusion of the Later Ring-Dykes about a centre near Achnaha, between Aodann and Meall Meadhoin. This complex is completely preserved, but it has obliterated large portions of

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the vent and cone-sheet complexes, and the Earlier Ring-Dykes. A few sheets, inclined towards the Achnaha centre, cut one of these later ring-dykes, and thus may belong to a partially developed group of Later Cone-Sheets.

(7) North-westerly dykes are fairly numerous, and are of various ages, for while some cut the sheets of the earlier cone sheet complex, others are cut by cone-sheets.

In Ardnamurchan as in Mull, Skye and other regions of Tertiary igneous activity in Scotland, the plateau-basalt magma, from its great extent, undoubted continuity, and early manifestation must be assumed to be the parent magma from which originated the diverse intrusive rock-types of more limited distribution. It would appear that local differentiation of this parent magma has in the main proceeded along two more or less distinct but converging lines, giving rise in both cases to rocks of increasing acidity and alkalinity, with granophyres and allied types as the ultimate products. The respective members of each suite of differentiates are linked together by common compositional factors that can only be of genetic significance.

The intrusive basic rocks of the Mull centre were found to constitute a group the components of which, on a chemical basis of comparison, were, *ceteris paribus*, richer in alumina, lime and magnesia than representatives of the normal magna series of which the plateau-basalt magma is to be regarded as the initial member. This normal magma in a differentiated and undifferentiated state manifested itself in Mull in a series of lavas, cone-sheets and sills—for the most part rocks of hypabyssal or extrusive character—which are closely paralleled by suites of similar rocks occurring in and around the Ardnamurchan centre. The major intrusions of Mull are mainly gabbros with attendant allivalites and eucrites, which as a group differ from the representatives of the normal magma, with similar percentages of silica, in the relatively high content of alumina and lime.

In Mull there are no other major intrusions that might represent a further stage in the differentiation of the basic magma. In the Ardnamurchan ring-dyke complex, however, we are more fortunately situated, for, here, we encounter plutonic intrusions that range from eucrite, by way of quartz-gabbros, to rocks of tonalitic and monzonitic affinities. The time intervals between successive members of the complex are relatively short and the rocks may be regarded as the result of progressive differentiation followed by intrusion under plutonic or quasi-plutonic conditions.

The relatively high proportion of lime and alumina which was a feature of the basic intrusions of Mull, Skye and Rum is maintained throughout the major intrusions of Ardnamurchan. The most natural inference to draw from such a compositional characteristic is that the differentiation of the parent magma was in part dependent upon the early separation and concentration of anorthite whereby enrichments in alumina and lime would be effected.

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Quartz-dolerite Cone-Sheets along shore south of Kilchoan, Ardnamurchan.

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The composition of the magma intruded during the cone-sheet period in Ardnamurchan was similar to that which obtained in Mull during the intrusion of the Late Basic Cone-Sheets of that region. The rocks that represent this phase of differentiation are mainly quartz-dolerites (Talaidh type) and it is interesting to note that the magma manifested in the great intrusion of Ben Hiant was compositionally identical with that which supplied material for the later cone-sheets.

This quartz-dolerite magma, represented in Mull and Ardnamurchan by innumerable sheet-like intrusions and by the larger mass of Ben Hiant, must be regarded as a very definite and extended stage in the scheme of differentiation.

Compared with the subsequent plutonic quartz-gabbros of the region, however, which have a similar silica-percentage, the hypabyssal cone-sheet magma is deficient in lime and alumina and there is a greater concentration of titanium and iron.

It is a remarkable coincidence that the phase which followed the eruption of the plateau-lavas in most of the Tertiary centres should be connected with an acid magma that gave rise to rhyolites and trachytes, for this would suggest that differentiation had already run its course. But in Ardnamurchan as in Mull there were several cycles of igneous activity, each commencing with a fresh influx of relatively undifferentiated basic magma. This frequent reappearance of the basic magma tends to substantiate the assumption that the plateau-basalt magma was the parent type, and to indicate how local were the regions in which the results of extreme differentiation were capable of self-expression.

HERBERT H. THOMAS.

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IV.—CHEMICAL WORK

In 1925 the quantitative analyses completed by the Chemical Department were mainly for Scottish Regional Memoirs. The following selection of the more interesting ones has been made for the present publication :—

799. *Bostonitic Trachyte.* Calciferous Sandstone Age. Small quarry, 264 yds. N. 28° E. of Windy Yet, 4½ m. E. 14° N. of Dunlop. 1-in. map, 22 ; 6-in., Ayr, 9 S.E. Sl. No. S21179.

803. *Plagiophyre* (presumably). Sill in Lower Old Red Sandstone Conglomerate. Pap Craig, 1 m. W. 17° N. of Eastfield, 2½ m. S.W. of Symington. 1-in., 23 ; 6-in., Lanark, 39 N.W. Sl. No. S24587.

800. *Andesitic Tholeiite.* 60 ft. N.W. Dyke, a continuation of the Acklington-Hawick Dyke. Lugton Water, 1,000 yds. S.W. of Smithy, Lugton. 1-in., 22 ; 6-in., Ayr, 8 S.E. Sl. No. S23845.

817. *Andesitic Tholeiite.* N.W. Dyke. 400 yds. N. of East Moneyacres, 1½ m. E.N.E. of Dunlop. 1-in., 22 ; 6-in., Ayr, 9 S.W. Sl. No. S24104.

818. *Tertiary Quartz Dolerite.* N.W. (The Barrmill) Dyke. Quarry 600 yds. E.S.E. of Hareshaw, 2 m. E. of Fenwick. 1-in., 22 ; 6-in., Ayr, 18 N.E. Sl. No. S24105.

802. *Tholeiitic Olivine Dolerite.* N.W. Dyke. 400 yds. W. of Middleton, nr. Lugton. 1-in., 22 ; 6-in., Ayr, 8 S.E. Sl. No. S23847.

Lab. No. ..	799.	803.	800.	817.	818.	802.
SiO_2	65·80	64·54	54·11	54·56	57·52	48·63
TiO_2	0·73	1·09	3·37	3·33	3·11	2·32
Al_2O_3	11·68	15·83	11·65	11·03	10·86	13·23
Fe_2O_3	6·83	1·75	2·76	2·87	2·30	3·16
Cr_2O_3	0·00	0·01	0·03	0·02	0·02	0·04
FeO	0·92	2·80	7·02	6·62	6·18	7·62
MnO	0·08	0·26	0·21	0·23	0·16	0·21
BaO	0·00	0·06	0·03	0·03	0·03	0·00
CaO	0·12	2·13	8·77	8·98	7·39	12·30
MgO	0·64	1·01	5·30	5·35	4·65	7·97
K_2O	4·82	2·95	1·75	1·43	2·26	1·13
Na_2O	5·51	5·25	2·63	2·83	3·02	1·20
Li_2O	0·00	0·00?	0·00	0·00	0·00	0·00
H_2O < 105°C. ..	0·93	0·42	0·68	0·71	0·96	0·75
H_2O > 105°C. ..	1·20	1·39	0·81	0·88	0·74	0·65
P_2O_5	0·40	0·00?	0·58	0·76	0·68	0·01
FeS_2	0·12	0·15	0·22	0·26	0·27	0·37
Fe_7S_8	0·00	0·00	0·00?	0·00?	0·00?	0·00?
C..	—	0·00?	0·00	0·00	0·00?	0·00
CO_2	0·12	0·27	0·05	0·10	0·04	0·21
Org. Matter ..	0·04	—	—	—	—	—
TOTALS ..	99·94	99·91	99·97	99·99	100·19	99·80
Analysed by ..	B. E. DIXON.					

0·00?='Trace' ; 0·00='Not found.'

811. *Grey Orthogneiss.* Coastal cliffs, 1155 yds. N. 25° E. of Clabhach Church, Coll. 1-in., 51 ; 6-in., Argyll, 36 N.E. Sl. No. S23029.

793. *Unscapolitized Hornblendic Orthogneiss.* Shore, 313 yds. W. 39° N. of Ballyphetrish, Tiree. 1-in., 42 ; 6-in., Argyll, 64 N.E. Sl. No. S23273.

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794. *Scapolitized Hornblendic Orthogneiss.* Approaching or enclosed in marble. Shore, 313 yds. W. 39° N. of Ballyphetrish. 1-in., 42 ; 6-in., Argyll, 64 N.E. Sl. No. S23274.

795. *Marble.* In Dun Gott paragneiss series. Dun Gott, Tiree. 1-in., 42 ; 6-in., Argyll, 65 S.W. Sl. No. S23021.

816. *Marble.* From Hogh Bay paragneiss series. Inside of fence by roadside, 333 yds. S. 37° W. of Uig, Coll. 1-in., 51 ; 6-in., Argyll, 50 N.W. Sl. No. S23028.

Lab.No.	811.	793.	794.	795.	816.
SiO_2	66·19	51·01	48·59	12·41	18·29
TiO_2	0·54	1·55	0·61	0·32	0·09
Al_2O_3	15·58	14·02	9·47	4·32	2·77
Fe_2O_3	1·38	7·18	7·54	1·05	1·11
FeO	2·90	4·19	3·98	0·25	0·00
MnO	0·37	0·17	0·24	0·04	0·42
(Co,Ni)O ..	0·00	0·00?	0·00?	0·00	0·00
CaO	4·20	12·11	19·06	38·46	31·44
MgO	2·11	5·79	4·91	5·73	15·52
K_2O	2·18	0·96	1·01	2·60	0·78
Na_2O	3·64	2·26	1·06	1·34	0·05
Li_2O	0·00	0·00	0·00	0·00	0·00?
H_2O < 105°C. ..	0·04	0·09	0·11	0·09	0·51
H_2O > 105°C. ..	0·63	0·28	1·15	0·84	4·01
P_2O_5	0·13	0·26	0·48	0·04	0·22
FeS_2	0·00	0·08	0·16	0·25	0·00
CO_2	0·39	0·07	1·78	32·24	24·84
TOTALS ..	100·28	100·02	100·15	99·98	100·05
Analysed by ..	E. G. RADLEY.	R. SUTCLIFFE.			E. G. RADLEY.

797. *Calcium Silicate Type of Dun Gott Paragneiss* (*Lewisian*). Shore, 280 yds. W. 32° N. of Dun Gott, Tiree. 1-in., 42 ; 6-in., Argyll, 65 S.W. Sl. No. S23023.

798. *Graphitic Schist.* In Dun Gott paragneiss series. Shore, 141 yds. E. 35° S. of Dun Gott, Tiree. 1-in., 42 ; 6-in., Argyll, 65 S.W. Sl. No. S23024.

796. *Garnet Gneiss.* In Dun Gott paragneiss series. Shore, 125 yds. W. 42° N. of Dun Gott, Tiree. 1-in., 42 ; 6-in., Argyll, 65 S.W. Sl. No. S23022.

813. *Granite Gneiss.* An acid granite of Ben Hogh. Coastal cliffs, 375 yds. W. 11° N. of Ballyhaugh, Clabhach, Coll. 1-in., 51 ; 6-in., Argyll, 36 S.W. Sl. No. S23020.

815. *Quartz Granulite.* Ben Feall outcrop of Hogh Bay paragneiss series (Lewisian). Ridges of rock on coastal cliffs, 358 yds. N. 10° E. of trig. stn. on Ben Feall, Coll. 1-in., 51 ; 6-in., Argyll, 50 N.W. Sl. No. S23026.

814. *Biotite Granulite.* From Hogh Bay paragneiss series. Coastal cliffs, 5 fur. N. 33° W. of Totronald, Coll. 1-in., 51 ; 6-in., Argyll, 36 S.W. Sl. No. S23027.

812. *Paragneiss.* From Clabhach series. In W. side of small bay. 280 yds. N. 33° W. of Clabhach Church, Coll. 1-in., 51 ; 6-in., Argyll, 36 N.E. Sl. No. S23025.

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Lab. No. ..	797.	798.	796.	813.	815.	814.	812.
SiO_2	49·37	53·72	59·71	68·97	81·89	64·23	76·15
TiO_2	1·25	0·61	1·83	0·38	0·06	0·67	0·12
Al_2O_3	17 18	6·74	15·45	14·66	9·10	15·87	5·55
Fe_2O_3	2·20	0·00?	6·99	1·36	0·17	0·03	0·87
FeO	0·95	0·00?	5·96	1·92	0·16	3·84	0·82
MnO	0·11	0·00?	0·06	0·38	0·26	0·42	0·30
(Co,Ni)O ..	0·00	0·00	0·00?	0·00	0·00	0·00	0·03
BaO	0·00	0·00	0·00	0·00	0·03	0·04	0·00
CaO	16·63	10·62	1·66	4·28	0·64	5·06	6·78
MgO	6·61	4·86	4·93	1·88	0·02	3·32	6·48
K_2O	1·67	1·95	1·60	1·42	7·11	1·68	0·66
Na_2O	0·18	3·32	0·66	4·18	0·11	2·86	0·49
Li_2O	0·00	0·00	0·00	0·00	0·00?	0·00?	0·00?
H_2O < 105°C.	0·14	1·06	0·04	0·03	0·03	0·05	0·08
H_2O > 105°C.	0·96	1·22	0·60	0·47	0·21	0·84	0·46
P_2O_5 ..	0·09	0·03	0·04	0·13	0·07	0·13	0·45
FeS_2	0·21	—	0·51	0·00	0·00	0·88	0·00
$(Fe,Mn)S_2$ ..	—	7·03	—	—	—	—	—
C	0·09	8·73	0·00	0·00	0·00	0·00	0·00
CO_2	2·65	0·11	0·12	0·13	0·28	0·10	0·95
Cl ..	0·00	0·00	0·00	0·00	0·00	0·00	0·03
Sn	—	0·00?	—	—	—	—	—
Pb	—	0·00?	—	—	—	—	—
TOTALS ..	100·29	100·00	100·16	100·19	100·14	100·02	100·22
Analysed by ..	R. SUTCLIFFE.			E. G. RADLEY.			

Lab. No. 798 was a particularly troublesome specimen owing to the presence of considerable amounts of pyrites and graphite. Although the figure for the total iron (3·23 per cent. Fe) can be regarded as correct, the respective values for the ferrous (0·70 per cent. FeO) and ferric iron (3·81 per cent. FeO) may require adjustment. The large amount of sulphur (3·75 per cent. S), which is not present in the rock as sulphate or as pyrrhotine-sulphide, could, within the limits of experimental error, be accommodated with the iron (and manganese, 0·04 per cent. MnO) as pyrites, if all of the iron is in the ferrous state. Petrographic examination does not reveal the presence of a mineral constituent containing ferric iron, and the pyroxene present may be destitute of the ferrous form of this element. Admitting these assumptions, the values are recalculated to the form shown under Lab. No. 798; there results a very satisfactory summation, which may be reasonable justification for regarding this analysis as affording something like truthful information as to the constitution of the specimen.

Concerning the qualitative examinations, inquiries, and research work in this department, there has been nothing of outstanding interest during the past year.

R. SUTCLIFFE.

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A.—*'Sand-ballers' or 'Giant's Marbles' in the Pectinatus Sands at Shotover Brickyard.*

B.—*Section of Gault and Kimmeridge Clay in the Culham Brickyard, Berkshire.*

[Taken from the Geological Survey memoir on 'The Country around Oxford' (*2nd Edition*), 1926].

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V.—PALÆONTOLOGICAL WORK

In London

F. L. KITCHIN, Sc.D., Ph.D., Palæontologist (District Geologist).
J. PRINGLE, Assistant-Palæontologist (Senior Geologist).
C. P. CHATWIN, Assistant-Palæontologist (Geologist).

In Edinburgh

G. W. LEE, D.Sc., Senior Geologist.

1. ENGLAND AND WALES

The second volume of the Palæontological Memoirs has now been completed by the issue of Parts 5 and 6 of the late Dr. Kidston's monograph on the Carboniferous plants. This represents all that Dr. Kidston actually finished and includes an account of nearly all the ferns and fern-like plants. Although Dr. Kidston left a considerable amount of manuscript material and photographs of specimens relating to the continuation of this work, some time must elapse before arrangements can be made for the issue of further parts. Dr. Kidston's collection has been unpacked and arranged in order in its original cabinets, and is accessible for reference. A few selected figured specimens have been arranged for exhibition in the Museum.

In the published account of the Virginia Water boring[1] the lowest bed of the Gault passed through in this boring was stated to belong to the Upper Gault. It was assumed in the absence of fossils that no Lower Gault was present in the lowest three feet. Since the publication of that account attention has been called to the fact that nodules containing ammonites were subsequently brought up by the debris-pump from the lowest bed. These have been examined by Dr. Spath and are found to give some representation of the zones of *Hoplites dentatus* and *Douvilleiceras mammillatum*. The Lower Gault at this locality, therefore, although very imperfectly represented is not entirely absent, as at first assumed.

Mr. Hester's collecting-work in the Chalk of the Guildford neighbourhood has shown that the assemblage of Mollusca characteristic of the Reussianum Sub-zone recurs at some localities above its normal level, thus having a greater vertical range than is usual in other districts.

Mr. Pringle has completed his work on the new edition of the memoir on the Special Oxford Sheet, which is now in the press. In connexion with the field-work, Mr. Pringle studied the Forest Marble Series near Corsham, Wiltshire, and obtained a series of the zone-fossil *Epithyris marmorea* (Oppel) from that type-area. An examination of the Corallian exposures in the Oxford district

[1] Appendix I, *in* 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 127.

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has revealed many points of interest. The Rhaxella Chert (Vertebrale or true Cordatum Zone) has been traced from a locality near Headington round the outcrop to near Wheatley Bridge. Ammonites were obtained at Littlemore from the argillaceous equivalents of the Coral Rag of more westerly localities, thus enabling a correlation to be made. Mr. Pringle's work at Shotover and Wheatley has confirmed the Kimmeridge age of the sandy beds formerly confused with the Portland Sands of the Dorset coast. At Wheatley, ammonites were obtained from the Rotundum Clay overlying the sands, confirming the correlation of the clay with the Swindon Clay.

Some of the ammonites obtained by Mr. Pringle from Kimmeridge Beds and Oxford Clay in Oxfordshire have already been figured by Mr. S. S. Buckman. The recent issue of Dr. E. Neaverson's monograph on ammonites from the Upper Kimmeridge Clay has made it possible to name, and to utilize in publications for the first time, many of the ammonites which occur in the Kimmeridge Clay of Oxfordshire. In this work, several specimens collected by Mr. Pringle from the Rotundum Beds of Chapman's Pool and the Oil Shales of Corton, Dorset, have been described and figured.

In the material collected by Mr. Templeman from the Carboniferous Limestone Series in North Cumberland, Mr. Pringle recognized some new brachiopods which, it is hoped, will be described by Miss H. M. Muir-Wood.

Interest has recently been aroused in the correlation of the Millstone Grit zones in South Wales[1]. During a recent revision of material for the purpose of the second edition of the Abergavenny Memoir, specimens collected by the Geological Survey in 1902 have been re-examined. These show clearly that in the Rhymney Bridge neighbourhood the Cancellatum Zone of Mr. Bisat's classification is represented. At one section, in the Pitwellt Stream, the presence of *Reticuloceras reticulatum*, mut. γ Bisat, together with *Gastrioceras cancellatum* Bisat, indicates a position about the base of the *Gastrioceras* zones.

The following specimens in the Museum have been figured, described or mentioned in publications:—

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1922
(Published 1925)

A Monograph of the Ammonoidea of the Gault. (Part ii)
By DR. L. F. SPATH, F.G.S.

Douvilleiceras mammillatum (*Schlotheim*), pl. v, fig. 1, p. 68.
,, *aff.* mammillatum (*Schlotheim*), pl. v, fig. 2, p. 71.
,, mammillatum, *var.* baylei *Spath*, pl. v, fig. 4, p. 70.
,, monile (*J. Sowerby*), p. 73 (2 specimens).
,, inaequinodum (*Quenstedt*), p. 74 (2 specimens).

[1] *Geol. Mag.*, 1925, p. 558; 1926, p. 47.

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Sonneratia kitchini *Spath*, pl. vi, fig. 14, p. 88 (6 specimens).
,, *aff.* kitchini *Spath*, pl. v, fig. 7, p. 88 (2 specimens).
,, sp. ind., pl. vi, figs. 15a, b, p. 90 (3 specimens).
Cleoniceras *aff.* cleon (*d'Orbigny*), pl. v, fig. 8, p. 91.
Cleoniceras ? devisense *Spath*, p. 95 (4 specimens).
Protohoplites puzosianus (*d'Orbigny*), pl. vi, fig. 1, p. 96 (2 specimens).
,, *aff.* raulinianus (*d'Orbigny*), pl. vi, figs. 6, 9, p. 98 (2 specimens).
,, sp. nov. (?), pl. viii, fig. 1, p. 99.
Leymeriella regularis (*Bruguière-d'Orbigny*), pl. vi, figs. 13a, b, p. 86.
,, tardefurcata (*Leymerie-d'Orbigny*), pl. vii, fig. 1, p. 84.
,, tardefurcata, *var.* densicostata *Spath*, p. 85 (3 specimens).
,, tardefurcata, *var.* intermedia *Spath*, p. 85.
Hoplites dentatus (*J. Sowerby*), pl. vii, fig. 5, p. 101 (3 specimens).
,, persulcatus *Spath*, p. 106.

A Monograph of the British Palæozoic Asterozoa. (Part vi)
By DR. W. K. SPENCER, M.A., F.G.S.

Onychaster flexilis (*Meek and Worthen*), pl. xxi, fig. 13.
Furcaster leptosoma (*Salter*), pl. xxii, fig. 4, p. 319.

A Monograph of the Fossil Macrurous Crustacea of England. (Part i)
By MR. H. WOODS, M.A., F.R.S.

Coleia antiqua *Broderip*, pl. ii, fig. 3, p. 13.

IN THE PALÆONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1923
(Published 1925)

A Monograph of the Ammonoidea of the Gault. (Part iii)
By DR. L. F. SPATH, F.G.S.

Hoplites benettianus (*J. de C. Sowerby*), pl. x, fig. 4 p. 116.
,, devisensis *Spath*, pl. xi, fig. 2, p. 124.
,, devisensis *Spath*, [coarsely ribbed form] p. 124 (2 specimens).
,, baylei *Spath*, pl. xi, fig. 5, p. 118.
,, pseudodeluci *Spath*, pl. xi, fig. 9, p. 122.
,, paronai *Spath*, pp. 115, 116 (2 specimens).
,, mirabiliformis ? *Spath*, p. 126.
,, dentatiformis *Spath*, p. 130.
,, sp. juv. ind. *aff.* canavarii ? *Parona and Bonarelli*, pl. ix, fig. 4, p. 112.
,, sp. juv., pl. x, figs. 7a, b, p. 118.
Anahoplites præcox *Spath*, pl. xi, fig. 4, p. 131.
,, planus (*Mantell*), p. 142.

A Monograph of the Fossil Macrurous Crustacea of England. (Part ii)
By MR. H. WOODS, M.A., F.R.S.

Coleia brodiei (*H. Woodward*), pl. vi, fig. 1, p. 19.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXX

The Volcanic series of Trefgarn, Roch and Ambleston, Pembrokeshire
By DR. H. H. THOMAS, M.A., and
PROFESSOR A. H. COX, D.Sc., Ph.D.

Callograptus salteri *Hall*, p. 526.
Dendrograptus flexuosus *Hall*
Dictyograptus irregularis *Hall*
Didymograptus extensus *Hall*
Phyllograptus *cf.* typicus *Hall*

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IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME XV, NINTH SERIES

Morphology and Zonal Distribution of some Chalk Terebratulids
By DR. M. R. SAHNI, B.A.

Pulchrithyris gracilis *Sahni*, pl. xxiii, figs. 6, 6a; pl. xxiv, fig. 12a, p. 362.
Carneithyris norvicensis *Sahni*, pl. xxiv, fig. 5; pl. xxvi, figs. 1, 1a, p. 367.
Magnithyris magna *Sahni*, pl. xxiii, figs. 1, 1a; pl. xxiv, figs. 1, 1a; pl. xxv, figs. 1, 1a, p. 367.
Chatwinothyris subcardinalis *Sahni*, pl. xxiii, fig. 9; pl. xxiv, fig. 4a; pl. xxvi, figs. 4, 4a, p. 369.
" symphytica *Sahni*, pl. xxiii, fig. 7; pl. xxiv, figs. 7, 7a; pl. xxvi, fig. 9, p. 369.
Gibbithyris gibba *Sahni*, pl. xxiii, figs. 4, 4a; pl. xxiv, figs. 3, 3a, p. 372.
" seafordensis *Sahni*, pl. xxvi, figs. 2, 2a, b, p. 373.
Neoliothyrina obesa (*Davidson*), pl. xxiii, fig. 8; pl. xxvi, fig. 10, p. 375.

IN THE GEOLOGICAL MAGAZINE, VOLUME LXII

On some English species of the genus Stylophyllopsis
By MR. S. H. STRAW, M.SC., F.G.S.

Stylophyllopsis mucronata (*Duncan*), text-fig. 7, p. 352.
" victoriae (*Duncan*), text-figs. 13–15, p. 359.

IN THE PROCEEDINGS OF THE YORKSHIRE GEOLOGICAL SOCIETY, VOLUME XX

The Carboniferous Goniatites of the North of England and their Zones
By MR. W. S. BISAT, F.G.S.

Homoceratoides divaricatum (*Hind*), p. 114 (3 specimens).
Gastrioceras cancellatum, *var.* crencellatum *Bisat*, p. 122 (2 specimens).

The nature of the Junction between the Lower Carboniferous and the Millstone Grit of North-west Yorkshire
By MR. L. J. CHUBB, M.SC., AND MR. R. G. S. HUDSON, M.SC.

Anthracoceras glabrum *Bisat*, p. 262.

IN PAPERS FROM THE GEOLOGICAL DEPARTMENT OF THE UNIVERSITY OF LIVERPOOL

Ammonites from the Upper Kimmeridge Clay
By DR. E. NEAVERSON, F.G.S.

Pectinatites pyriticus *Neaverson*, pl. i, fig. 4; text-fig. A 14, p. 17.
" aulacophorus *S. Buckman*, pl. i, fig. 5; text-fig. A 15, p. 15 (2 specimens).
Pallasiceras concinnum *Neaverson*, pl. i, fig. 7; text-fig. A 11, p. 19.
" gracile *Neaverson*, pl. i, figs. 8, 9; text-figs. 1–6, 12, p. 20 (2 specimens).
" pringlei *Neaverson*, pl. i, fig. 10, p. 20.
Aposphinctoceras variabile *Neaverson*, pl. ii, figs. 5a, b (2 views), p. 29.
Allovirgatites woodwardi *Neaverson*, pl. iii, figs. 1a, b (2 views); text-fig. B 4, p. 29.
Holcosphinctes pallasioides *Neaverson*, pl. iii, fig. 5; text-fig. B10, p. 35.
Virgatosphinctoides grandis *Neaverson*, pl. iv, fig. 2, p. 13 (2 specimens).
" nodiferus *Neaverson*, p. 14.
Sphinctoceras distans *Neaverson*, pl. iv, fig. 3; text-figs. 12–15, p. 23.
Paravirgatites kimmeridgensis *Neaverson*, pl. iv, fig. 4, p. 33.

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IN THE TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, VOLUME LIV. Part ii. (No. 2)

Contributions to the Study of the Old Red Sandstone Flora of Scotland.

ii. *On a Sporangium-bearing branch-system from the Stromness Beds*

By PROF. W. H. LANG, F.R.S.

Hostimella racemosa *Lang*, pl. iv, figs. 71–75, p. 272 (3 specimens).

IN TYPE AMMONITES, VOLUME V

By MR. S. S. BUCKMAN, F.G.S.

Apoderoceras tardarmatum *S. Buckman*, pl. dxliiA ; pl. dxliiB.
Katakosmokeras degradatum *S. Buckman*, pl. dxlviii.
Pleurocephalites liberalis *S. Buckman*, pl. dlviii.
Ringsteadia pseudocordatus (*Blake and Hudleston*), pl. dlxA ; pl. dlxB.
Shotoverites pringlei *S. Buckman*, pl. dlxii.
Peltoceratoides torosus (*Oppel*), pl. dlxiii, figs. 1–3.

IN TYPE AMMONITES, VOLUME VI

By MR. S. S. BUCKMAN, F.G.S.

Kellawaysites multicostatus (*Petitclerc*), pl. dlxxxvii, figs. 1, 2.
Loboplanulites longilobatus *S. Buckman*, pl. dxcvi, figs. 1, 2.
Anakosmokeras effulgens *S. Buckman*, pl. dxcviiA ; pl. dxcviiB.
Gulielmites sedgwicki (*Pratt*), pl. dxcviii.
Keratinites cornutifer *S. Buckman*, pl. dcii.
Binatisphinctes fluctuosus (*Pratt*), pl. dcxv.
Plasmatoceras plastum *S. Buckman*, pl. dcxvii, figs. 1–3.
Plasmatites crenulatus *S. Buckman*, pl. dcxviii, figs. 1–3.

IN MEMOIRS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN; PALÆONTOLOGY—VOLUME II. (Parts 5, 6)

Fossil Plants of the Carboniferous Rocks of Great Britain

By DR. R. KIDSTON, LL.D., F.R.S., F.G.S.

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,, zeilleri *Vaffier*, pl. cviii, figs. 7, 7a, 8, p. 421.
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Asterotheca arborescens (*Schlotheim*), pl. cxiv, fig. 1, p. 483.
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,, crenulata (*Brongniart*), pl. cxiv, figs. 4, 4a, b, p. 516.
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,, oreopteridia (*Schlotheim*), pl. cxvlii, figs. 1, 1a, 2, 2a ; pl. cxix, figs. 1–4 ; text-figs. 51, 52, p. 497.
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,, lamuriana (*Heer*), pl. cxxvi, figs. 1, 1a, b, 2, 2a, b, p. 532.
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,, bifidum (*Lindley and Hutton*), pl. ciii, figs. 2–9; text-fig. 44, p. 454.
Telangium (?) potieri (*Zeiller*), pl. cii, figs. 2–4, p. 461.
Telangium sp., p. 464.
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,, camertonensis *Kidston*, pl. cxv, figs. 2, 2a; text-fig. 77, p. 567.
,, cisti (*Brongniart*), pl. cxxxv, figs. 1, 1a; text-fig. 74, p. 559.
,, fletti *Kidston*, pl. cxxv, figs. 2, 2a; pl. cxxxiii; pl. cxxxiv, figs. 1, 1a, b; text-fig. 76, p. 564.
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,, coarctata (*Stur*) ? non (*Roehl*), pl. cxl, figs. 2, 2a, b; pl. cxliii, figs. 3, 3a, p. 663.
,, daviesi *Kidston*, pl. cxlvi, figs. 1, 1a, 2, 3, p. 640.
,, dernoncourti *Zeiller*, pl. clii, figs. 1–3, 3a; text-figs. 96, 97, p. 651.
,, hirta (*Stur*), pl. cxli, figs. 1, 1a; pl. cxliii, fig. 4; pl. cxliv, figs. 2, 2a, p. 626.
,, jacquoti (*Zeiller*), pl. cl, fig. 1; pl. cli, figs. 2, 2a, 3, text-fig. 98, p. 655.
,, latifolia (*Brongniart*), pl. cxliv, fig. 7, p. 643.
,, lobatifolia *Kidston*, pl. cxl, figs. 3, 3a, p. 628.
,, muricata (*Schlotheim*), pl. cxxxviii, figs. 1, 1a, 2; pl. cxliv, fig. 3; pl. cxlv, p. 592.
,, nervosa (*Brongniart*), pl. cxxxviii, figs. 3, 3a, 4, 4a; pl. cxliv, figs. 1, 4, 4a, 6, 6a; pl. cliii, fig. 7, p. 601.

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Mariopteris nervosa, *forma* oblongata *Brongniart*, pl. cxl, figs. 1, 1a; pl. cxliii, figs. 1, 1a, b, 2, 2a; pl. cxliv, fig. 5, p. 604.
,, nobilis (*Achepohl*), pl. cxlix, figs. 4, 4a, 5; pl. cliii, fig. 8, p. 639.
,, obovata *Kidston*, pl. cxlix, figs. 6, 6a, 7, 7a, p. 660.
,, sauveuri (*Brongniart*), pl. cxlii, figs. 1–3, p. 622.
,, soubeirani *Zeiller*, pl. cxlviii, figs. 1, 1a, b, 2, 2a, p. 648.
,, sp. (A), pl. cxlvi, figs. 4, 4a, p. 665.
,, sp. (B), pl. cxlvii, fig. 2, p. 666.
,, sp. (C), pl. cxlviii, figs. 3, 3a, p. 666.
,, sp. (D), pl. cxlix, figs. 1–3, 3a, p. 667.
,, sp. (E), pl. cli, fig. 1, p. 669.
,, sp. [stem giving off roots], pl. cliii, fig. 9, p. 670.
Pecopteris armasi *Zeiller*, pl. cxxxv, figs. 2, 2a, b.; text-fig. 80, p. 576.
,, bioti *Brongniart*, pl. xcvi, fig. 4, p. 581.
,, integra (*Andrae*), pl. cxxxvii, figs. 4, 4a, p. 579.
Pecopteris ? hepaticaeformis *Kidston*, p. 583 (2 specimens).
Ptychocarpus unitus (*Brongniart*), pl. cxxxi, figs. 2, 2a, 3–5, 5a, 8, p. 548.
,, ,, *forma* emarginatus *Göppert*, *pro. sp.*, pl. cxxxi, figs. 1, 6, 6a, 7, 9, 9a, p. 550.
Fertile fragment of a fern or fern-like plant, pl. civ, fig. 4, p. 474.

2. Scotland

Dr. Lee revised the Carboniferous section of the Arran Memoir, and found it necessary to re-examine all the invertebrate fossils recorded in the original edition. In a number of cases the old naming had to be modified, but this has not introduced any change in the stratigraphical scheme of the late Mr. W. Gunn.

The fossils collected during the year in Scotland and Northumberland are from known areas under revision; consequently there is little of purely palæontological interest that could be mentioned here. But the identifications of fossils from various borings and exposures have proved to be of value in stratigraphical correlations, and some are cited elsewhere in the reports of the field-officers concerned.

F. L. Kitchin.

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VI.—MUSEUM OF PRACTICAL GEOLOGY

The completion of the temporary repairs to render the building safe enabled the Museum staff to make some progress towards renovating the collections, which had been considerably disorganised in the course of the work. It was found that owing to the encroachments on the floor space large reductions in the exhibited collections were necessary before the public could be admitted, and approximately 20 cases were withdrawn to store and the specimens transferred to the reference collections. The remaining exhibits have been cleaned and reorganised and the collections were opened to the public on August 4th.

In the present condition of the Museum it is naturally impossible to display adequately such material as is on exhibition or to organise new exhibits demanding floor-space, but the unsightly wooden structures have been screened off, and educational sets of maps, photographs and diagrams have been installed on the wall-space thus created. Amongst these may be mentioned a complete set of one-inch maps of the London District and a large series of enlargements of Survey photographs illustrating geological processes. The success of these exhibits has been encouraging, and plans have been completed to enlarge and supplement them. Space has been found on the ground floor for the Kidston Collection of Carboniferous Plants, and some of the more noteworthy specimens are now on exhibition.

In the Mineral Department the collections have been cleaned and reorganised, and the cataloguing of unregistered material is approaching completion. Photographs and specimens from the Wembley exhibit have been arranged to illustrate the Special Reports on iron ores, especially Vol. XXIX, and the recent additions to the gemstone collection have been arranged and set out in a prominent position.

In the Library the number of readers and enquirers has noticeably increased since the reopening of the Museum. Owing to the unsafe condition of the floor of the library annexe on the mezzanine floor and of the library balcony it was necessary to convert the ground floor passage into a two-deck book-store to which upwards of 5,000 volumes have since been transferred. The revision and extension of the exchange and presentation list has resulted in a large increase in the accessions. A further instalment of important pamphlets and reports on water-supply was received from the executors of the late W. Whitaker, F.R.S., and a collection of 80 pamphlets on Indian geology was presented by the executors of the late Sir H. H. Hayden.

A set of about 8,000 catalogue cards (both author and subject) of the Geological Survey of the United States has been received from the United States Library of Congress. These are being

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sorted and arranged, as time allows, and the author section will shortly be available for use.

New periodicals added during 1925 include:—

Senckenberg. Naturforschende Gesellschaft,
Frankfurt-a-M.
Aus Natur und Museum,
Senckenbergiana.
Institute of Practical Geophysics, Leningrad.
Bulletin.
Nebraska State Museum, Lincoln.
Bulletin.
McGill University, Montreal.
Publications.
American Museum of Natural History, New York.
American Museum Novitates.
Natural History.
National Academy of Sciences, Philadelphia.
Proceedings.
Imperial University, Tokyo.
Journal of the Faculty of Science.
Geodynamische Probleme, Berlin.
Zeitschrift fuer Geschiebeforschung, Berlin.
Good Roads, Birmingham.
Pan-American Geologist, Des Moines.
Zeitschrift fuer Geomorphologie, Leipzig.
Refractories Journal, Sheffield.

W. F. P. McLintock.

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APPENDIX I

The Basalt of Little Wenlock (Shropshire)

By R. W. Pocock, M.Sc.

Plate X. Text-figures 14, 15.

INTRODUCTION

The basalt of Little Wenlock[1] is exposed (1) between the western side of the Coalbrookdale Coalfield and the Wrekin; (2) in Lydebrook Dingle; and (3) in three inliers: at Doseley, Horsehay,

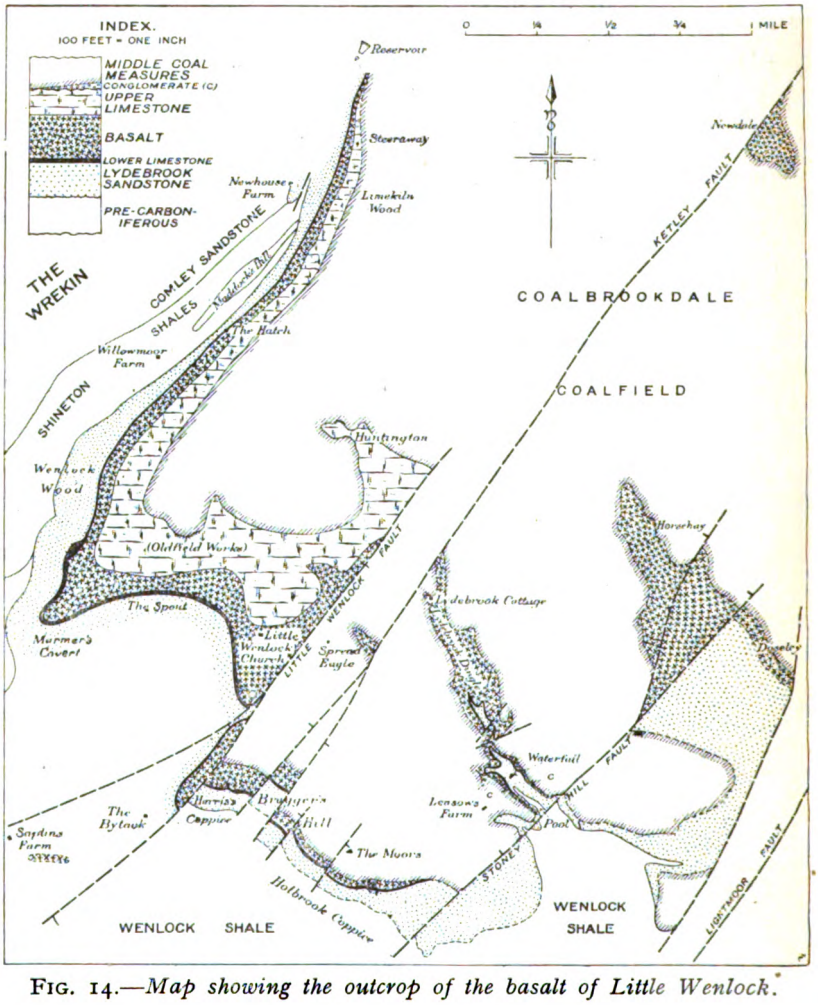

FIG. 14.—*Map showing the outcrop of the basalt of Little Wenlock.*

and Newdale. There is also (4) a small outlier of the rock at Saplins Farm, south-west of Little Wenlock (*see* Map, Fig. 14).

[1] New Series One-inch maps 152 (Shrewsbury) and 153 (Wolverhampton); Old Series geological map 61 N.E.

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At the northern end of its outcrop near Steeraway the basalt makes no feature; but between the Hatch and Wenlock Wood it forms a well-marked escarpment, facing the Wrekin and trending south-westward. From the southern end of Wenlock Wood the outcrop swings eastward to Little Wenlock. South-east of Little Wenlock the basalt is cut off by the Little Wenlock Fault, east of which it forms the edge of the high ground at Bragger's Hill and the Moors, in which direction it appears to thin out. At the northern end of Lydebrook Dingle the basalt is well developed, but appears to thin out southward, and at the southern end of the dingle it is absent.

At Doseley the rock is finely displayed in a large quarry for road-metal, and columnar structure is very well marked. At Horsehay another large quarry shows a fine section of the basalt.

At Newdale there is very little evidence of the outcrop of the basalt at the surface, but the Derbyshire Level, a water-level driven from Ketley to the Old Park, is said to have passed through basalt for the greater part of its length of 1½ miles.

The small outlier at Saplins Farm appears to be preserved between two branches of the Little Wenlock Fault.

PREVIOUS LITERATURE

Previous accounts of the Little Wenlock basalt are limited and lacking in detail. They show strong difference of opinion as to the age of the rock. The following list gives the chief references to the subject, together with a brief summary of each author's conclusions:—

1839. R. I. MURCHISON, 'The Silurian System,' pp. 109 and 110.—Regards the basalt as of later date than the Coal Measures. He mentions the presence of olivine and of prehnite at Horsehay. He also states that in the western limit of the tract there are greenstones of a coarse grain, which pass into tuffaceous amygdaloids.

1840. J. PRESTWICH, *Trans. Geol. Soc.*, ser. 2, vol. v, p. 449, etc.—Mentions the occurrence of amygdaloidal structure, with concretions of prehnite and oxide of iron. He says (pp. 450–1) "I could not learn that the coal-measures were altered by the proximity of these igneous products; and at the old pits at Little Wenlock, where the two rocks are brought into abrupt juxtaposition by a large fault. . . intelligent colliers have assured me, that the coal shales and sandstone were worked up to their point of contact with the 'black rock' or basalt, without presenting the slightest alteration; neither is the regularity of the plane of dislocation at all disturbed in this part of its course. . . I am, therefore, inclined to consider that the basalt and trap were ejected previously to deposition of the carboniferous series." He appears, however, to have thought that some of the basalt is intrusive, for he says (p. 451); "Other small bosses of greenstone and basalt appear on the side of the canal near the Horsehays, at Coalmoor Farm, Harris Coppice. . . Saplin Farm, &c.; the two first protruding into the coal-measures, the last into the Wenlock shale; and that at Harris Coppice separating the two formations."

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1855. Geological Survey Map, Old Series, 1 inch to 1 mile, Sheet 61 N.E. Surveyed by D. H. Williams, W. W. Smyth, W. T. Aveline, E. Hull, and A. C. Ramsay.—In this map the 'greenstone' (camptonite) of Maddock's Hill is included in the outcrop of the basalt.

1858. Geological Survey, Horizontal Sections, Sheet 54, No. 1. By A. C. Ramsay, D. H. Williams, and E. Hull.—The basalt is here shown as extending underground east of the Lightmoor Fault.

1859. Geological Survey Explanation of Horizontal Sections, Sheet 54, No. 1. By A. C. Ramsay.—The author of this pamphlet estimates the thickness of the basalt at 150 ft., and says: "The manner of its outcrop like a thick stratum, the unaltered state of the adjoining Carboniferous rocks, and the recurrence of the basalt in the manner of a bed exposed by denudation, leads to the inference that, though the point of eruption is unknown, it was originally a flow of basaltic lava of limited extent poured out on the floor of the Carboniferous sea."

1860. Geological Survey, Horizontal Sections, Sheet 58, No. 2. By A. C. Ramsay, D. H. Williams, and E. Hull.—The section passes through Steeraway and Newdale. The basalt is shown as extending underground about 1½ miles east of Newdale.

1869. C. EYTON, 'Notes on the Geology of North Shropshire,' 8vo, p. 35.—Refers to the basalt at Horsehay as a volcanic outburst of later Carboniferous age.

1870. S. ALLPORT, 'On the Basaltic Rocks of the Midland Coal-fields,' *Geol. Mag.*, p. 159.—Mentions the occurrence, in basalt from Little Wenlock, of pseudomorphs after olivine, in some of which the change is not complete, and also examples of the chloritic mineral filling up spaces between the crystals of felspar and augite. He says (p. 161): "With respect to the precise age of these rocks, there is no satisfactory positive evidence, except in Derbyshire, where they clearly alternate with the Carboniferous Limestone, but there is a considerable amount of negative evidence to show that all are probably contemporaneous with the Coal-measures as *a whole*."

1874. S. ALLPORT, 'On the Microscopic Structure and Composition of British Carboniferous Dolerites,' *Quart. Journ. Geol. Soc.*, vol. xxx, p. 529.—Refers (p. 550) to the rock near Little Wenlock as "a rather finely crystalline dolerite, containing many very good examples of compound pseudomorphs of olivine; in most of them calcite forms the central part, and is traversed and surrounded by serpentine or chlorite; the augite is very abundant, and occurs in small grains; the plagioclase is but slightly altered."

1894. C. LAPWORTH and W. W. WATTS, 'The Geology of South Shropshire,' *Proc. Geol. Assoc.*, vol. xiii (1893–4), p. 343.—Under the heading 'Post-Carboniferous Intrusive Rocks' the authors state that near the Wrekin the basalt forms the floor on which the Carboniferous Limestone rests.

1897. A. GEIKIE, 'The Ancient Volcanoes of Great Britain,' vol. ii, p. 103. Under the heading 'Eruptive Rocks in the Midland Coal-fields' the author says of the Coalbrookdale Coalfield: "In this interesting district a sill of rather finely crystalline olivine-dolerite, which is estimated to be nearly 200 feet thick, is traceable from near Little Wenlock for three miles to the north, intercalated between the Carboniferous Limestone and the Silurian rocks underneath. It appears to underlie the western part of the Coal-field, for it is exposed by denudation in several valleys between Little Wenlock and Great Dawley. Owing to the thinning out of the Carboniferous Limestone in an easterly direction, the sill gradually comes to have the

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Millstone Grit on its upper surface, and at one point is represented on the Geological Survey map as even intruded into the Coal-measures. Here again we have an intrusive sheet of later date than at least the earlier part of the Coal-measures, and no evidence of any superficial outflow of volcanic material."

1910. C. LAPWORTH and W. W. WATTS, 'Geology in the Field,' *Geol. Assoc.*, 8vo, p. 766.—The authors refer to the rocks as post-Carboniferous olivine-dolerites, and state that they are intrusive into the Coal Measures at Little Wenlock. "A precisely similar sill [to those capping the Titterstone and Brown Clee Hills] is intrusive below the Carboniferous Limestone of the Hatch, coming between it and the Shineton Shales." They say also that "The rocks are well-preserved olivine-dolerites, indistinguishable in their lithology, as Allport showed, from the Tertiary rocks of Antrim and West Scotland. It is more than likely that these rocks are also Tertiary in age." They further state that there are no contemporaneous volcanic rocks of Carboniferous age in Shropshire.

1924. 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), p. 48.—Mentions the columnar jointing at Doseley.

1925. W. W. WATTS, 'The Geology of South Shropshire,' *Geol. Assoc.*, 8vo, p. 31 and Figs. 5 and 6 on p. 9; also Bracewell, pp. 71–73. (See 1925, Watts, below.)

1925. 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), p. 43.—It is here remarked that accumulating evidence suggests that the igneous rocks are, at any rate in part, contemporaneous with the Carboniferous Limestone.

1925. W. W. WATTS, 'The Geology of South Shropshire,' *Proc. Geol. Assoc.*, vol. xxxvi, p. 351.—The author says of the Lydebrook Sandstone: "This is intruded upon by a sill of olivine-dolerite . . . and conformably succeeded by the Carboniferous Limestone of Steeraway and the Hatch." Moreover, the rock is shown as an intrusion in Figs. 30 and 31 on p. 329 by W. W. Watts and S. Bracewell. In the same publication the latter, in 'Notes on the Lowest Carboniferous Rocks of the Wrekin District,' says (p. 391) that near Newhouse Farm the dolerite sill occurs in the [Lydebrook] sandstone; that the sill rises in the succession, and where crossed by the road that runs due south from Little Wenlock a little of the limestone is seen under it; and that at Bragger's Hill the only limestone seen is wholly below the sill. On p. 392 we read: "At Lydebrook Cottage the flanks of the valley show that the [Lydebrook] sandstone is covered by Carboniferous Limestone, and that by a thick development of the dolerite sill." Again, on p. 393: "the dolerite, which succeeds in penetrating the Lydebrook Sandstone and the Limestone, might have been held down by the base of the 'Millstone Grit' which it seems always unable to pierce."

From the above *résumé* of the literature it appears that recent opinion has been in favour of the intrusive character of the igneous rock and of its post-Carboniferous or even Tertiary age.

STRATIGRAPHICAL RELATIONS AND AGE OF THE BASALT

The basalt is associated with the Carboniferous Limestone, of which there are two separate divisions[1]: a thin limestone (the

[1] The failure of previous observers to discover that there are two separate and distinct limestones (the Upper and the Lower) is probably what led some of them to regard the basalt as intrusive.

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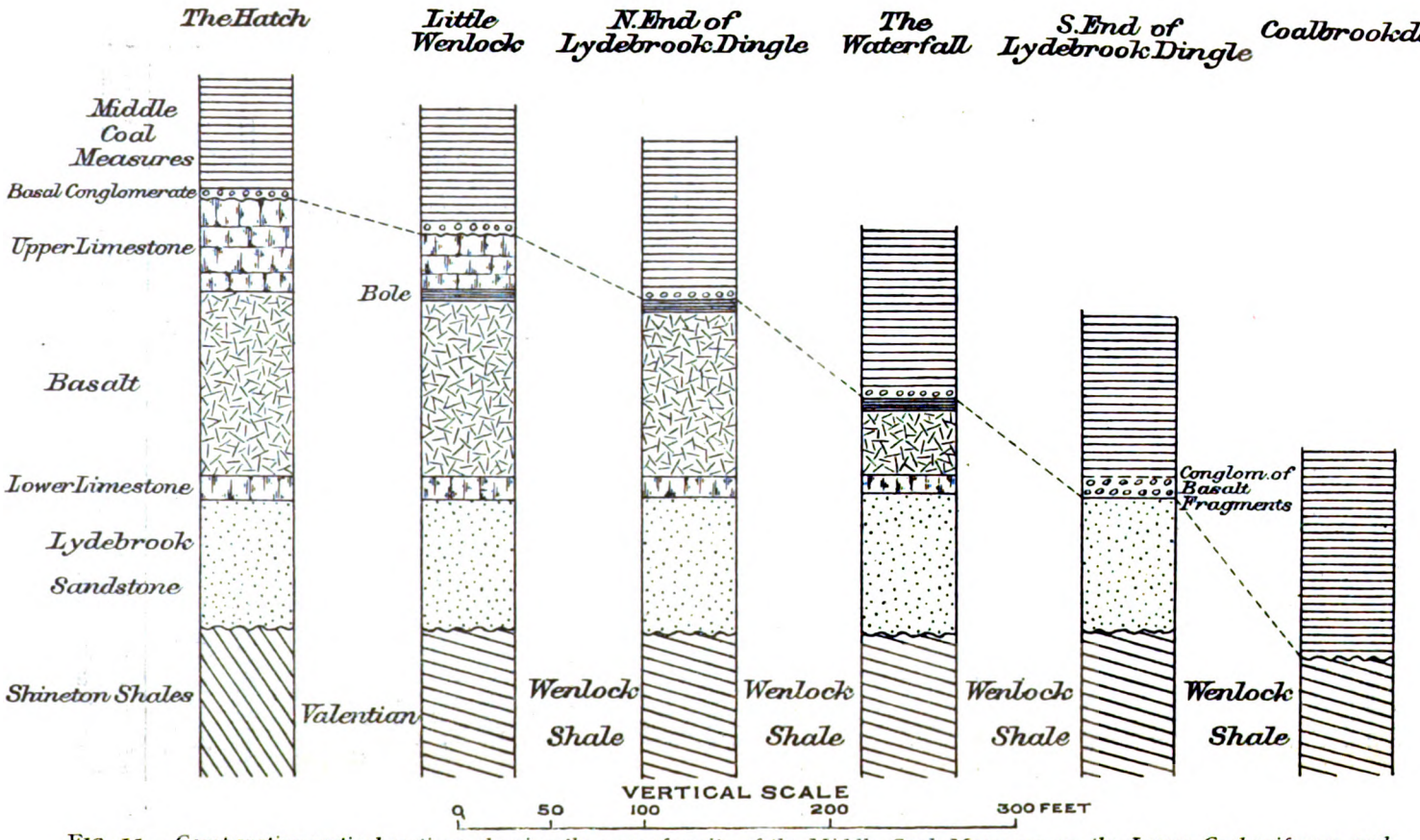

FIG. 15.—*Comparative vertical sections showing the unconformity of the Middle Coal Measures on the Lower Carboniferous and Basalt, Little Wenlock.*

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Lower Limestone) below the basalt and a thicker development (the Upper Limestone) above it. The Lower Carboniferous rocks rest upon various members of the Cambrian and Silurian systems, and are covered unconformably by the Middle Coal Measures (Fig. 15, p. 144). Where most complete, the subdivisions in question are as follows, in descending order:—

	Ft.
Middle Coal Measures :—	
Shales and sandstones, with a basal conglomerate in places	—
Unconformity.	
Carboniferous Limestone Series :—	
Upper Limestone (D_2), comprising bands of grey limestone, sandstone and shale .. .. about	50
Basalt .. .. about	100
Lower Limestone (D_2), a band of nodular creamy-yellow limestone .. .. 2 ft.	to 6
Lydebrook Sandstone (D_1), fine to coarse yellowish sandstone with a few shaly beds .. .. about	70
Unconformity.	
Pre-Carboniferous : Silurian and Cambrian	—

Relations to the Underlying Rocks.—In the old quarries near the reservoir at the northern end of the main outcrop of the basalt the sections are now very obscure; but the rock appears to rest on a thin bed of creamy-yellow, nodular limestone (the Lower Limestone), which seems to pass eastward under the basalt, while to the west there is clear evidence of the presence of the Lydebrook Sandstone.

At Newhouse Farm (west of Limekiln Wood) the Lydebrook Sandstone, which has here yielded *Buxtonia sp.*, *Productus sp.*, *Schellwienella ?*, and *Aviculopecten sp.*, is exposed in a pit 50 yds. north-east of the house, and again in two pits 100 and 150 yds. east-south-east of the house. Fragments of creamy limestone have been found 50 yds. east of the last pit, while the basalt is exposed only a few yards farther to the east.

The outcrop of the Lydebrook Sandstone passes to the east of Maddock's Hill, and about 250 yds. north-east of the Hatch the presence and position of the creamy-yellow limestone above it, and of the basalt overlying the limestone, can be traced by fragments in the soil.

In the lane at the Hatch there appear to be about 60 ft. of Lydebrook Sandstone dipping south-eastward at about 30° and overlying the Shineton Shales. Between the sandstone and the overlying basalt, which is exposed in the lane, there are indications of the presence of the thin nodular creamy-yellow limestone; for many fragments of it can be found in the bank just opposite the cottage.

Limestone fragments occur again 200 yds. east of Willowmoor Farm, with yellow sandstone fragments to the north-west and basalt to the south-east. The sandstone crops out in the road south of Willowmoor, and between it and the overlying basalt there are indications of the creamy limestone in the bed of the road. To the

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south-west of the road and east of Wenlock Wood the limestone band can be traced with ease across the ploughed fields by the abundance of its fragments and fossils. The positions of the sandstone below and the basalt above the limestone are equally well defined by their fragments in the soil. In Wenlock Wood the Lydebrook Sandstone has yielded *Composita ambigua* (J. Sow.), *Productus hemisphaericus* J. Sow., *P. sp.* [cf. *P. maximus* (M'Coy)], and *Bellerophon sp.*, a fauna that indicates its D_1 age.[1] The limestone crosses the lane that runs from Wenlock Wood to Little Wenlock at a point about 50 yds. from the southern corner of the wood, and the basalt can be seen above it in the bed of the lane just to the east. In the field south of the lane the outcrop of the limestone is marked by an abundance of fossiliferous fragments; these have yielded *Alveolites septosus?* (Flem.), *Lithostrotion junceum* (Flem.), *Syringopora sp.*, *Chonetes comoides* (J. Sow.)[2], and *Productus sp.* This fauna indicates a D_2 age. The outcrops of the overlying basalt to the east and of the underlying Lydebrook Sandstone to the west are easily followed.

Many fragments of the same limestone occur just below the basalt outcrop at the northern end of Marmer's Covert, a small coppice adjoining Spout Lane; and there are also indications of it below the edge of the basalt in the fields on the north side of the lane.

The base of the basalt crosses an old lane 150 yds. west of Little Wenlock church. Here the underlying sandstone can be seen, although the thin limestone has not been detected. The basalt is well exposed in an old quarry and in the adjacent lane 400 yds. south of the church, where it can be seen to rest upon creamy nodular limestone with *Lithostrotion junceum* (Flem.) and *Productus sp.* The outcrop of the limestone can be traced, just below the basalt, to the north-west across the field west of the lane by the abundant fragments in the soil.

About 100 yds. south of the old quarry the Little Wenlock Fault, throwing down to the south-east, crosses the lane, and the basalt forms a strong feature trending south-westward towards the Bytack. The limestone appears to crop out at the foot (*i.e.*, the north-west margin) of this feature, for fragments of creamy limestone occur in the soil. A branch of the Little Wenlock Fault touches the west side of Harris's Coppice (at Bragger's Hill). East of this fault the basalt is well exposed in the Buildwas road, where it clearly overlies the creamy nodular limestone and Lydebrook Sandstone, which crop out lower down the lane.

At Bragger's Hill, just to the east of the lane, the relations of the basalt to the limestone and underlying sandstone are not clearly seen, as the escarpment is cut by several minor dip-faults; but along the north side of Holbrook Coppice, south of the Moors,

[1] See also S. Bracewell, *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 390.

[2] Mr. J. Pringle, who has named the fossils, remarks that this shell is identical with the form figured by Garwood as an index-fossil of a band at the summit of D_1 in the North-Western Province.—See *Proc. Geol. Assoc.*, vol. xxvii, 1916, Plate 16, Fig. 4.

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the basalt can again be proved to overlie the limestone, which here again rests on the sandstone.

An outlying patch of basalt at Saplins Farm appears to have been preserved by being let down between the Little Wenlock Fault and the branch fault to the south; but the relations of this patch to the limestone and sandstone are not clear.

In Lydebrook Dingle there is abundant evidence of the superposition of the basalt on the Lower Limestone. About 550 yds. down the dingle from the Little Wenlock and Horsehay road the limestone crops out from below the basalt in the bed of the stream. It is of the usual creamy-yellow colour, nodular in part, and crowded with fossils. Farther down stream the underlying Lydebrook Sandstone is exposed. A trial trench, cut on the east side of the dingle to prove the extent of the basalt, showed the limestone bed with *Lithostrotion martini* Edw. & Haime, *Lonsdaleia sp.*, and *Syringopora sp.* cropping out just at the base of the basalt.

About 250 yds. down stream from the first outcrop of the limestone the dingle is crossed by a fault; this brings the limestone in again in the bed of the stream, where it can be seen to underlie the basalt and to overlie the Lydebrook Sandstone as before. A second fault, crossing the dingle 100 yds. south of the last, again brings in the limestone with the overlying basalt. From this point the outcrop of the limestone climbs up the sides of the dingle and directly overlies the Lydebrook Sandstone, over which the brook falls in a 25-ft. waterfall at its junction with a small stream from the west. Above the sandstone and 100 yds. north of the waterfall a good exposure of the limestone yielded *Lithostrotion junceum* (Flem.), *Lonsdaleia floriformis* (Mart.), cf. mut. *laticlavia* S. Smith, and *Syringopora sp.*

At this point a bed, about 2 ft. thick, of what appears to be an ash (E.12849)[1] separates the limestone from the overlying basalt. This bed is bright red in colour and in places resembles a bole (p. 149). A similar bed of ashy rock, from 1 to 2 ft. thick, intervenes between the limestone and the basalt in the bed of the tributary stream coming in from the west. In this stream the ascending succession of sandstone, limestone, and basalt is clearly displayed, the limestone yielding the same fauna as at the last locality.

A very short distance down the dingle below the waterfall both limestone and basalt appear to die out.

In the Doseley and Horsehay inliers, which are contiguous, the base of the basalt is not exposed; but at the former locality a pebbly coarse sandstone, believed to be the Lydebrook Sandstone, can be seen dipping towards the columnar basalt in the quarry, and there is little doubt that it passes eastward under the basalt. The inlier at Newdale yields no evidence of the floor on which the basalt rests.

From the foregoing details it will be seen that the basalt,

[1] The numbers in brackets refer to the rock-slides in the English series of microscope slides at the Geological Survey Office, Jermyn Street, London.

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throughout its main outcrop and in Lydebrook Dingle, rests on a thin bed of Carboniferous Limestone (the Lower Limestone), of peculiar lithological character, that yields a fauna indicative of the D_2 subzone of Vaughan. This thin limestone band succeeds the Lydebrook Sandstone (D_1), and there is no evidence that the basalt transgresses it or penetrates the underlying sandstone. These facts alone strongly suggest the extrusive character of the igneous rock.

Relations to the Overlying Rocks.—At the northern end of the main outcrop, in the old quarries near the reservoir, the basalt appears to be overlain by sandstone and black shale belonging to the Carboniferous Limestone Series, though no clear section is now available. At Steeraway also the sections are now much overgrown, and we cannot do better than take the details given by Prestwich[1], who records 39 ft. of Coal Measures overlying 49½ ft. of Carboniferous Limestone. According to his section the Coal Measures consist of 9 ft. of shale on 30 ft. of pebbly sandstone, while the Carboniferous Limestone is made up of alternate beds of limestone, shale, and sandstone. The lowest beds, numbered 20, 21 and 22, are:—very impure clayey limestone, 4½ ft.; bituminous shale, 1½ ft.; hard sandstone, 4 ft.; and he states that the basaltic rocks appear a few feet below this sandstone bed.

In Limekiln Wood, at a point 800 yds. north-east of the Hatch, a good exposure shows the pebbly sandstone base of the Coal Measures resting on the highest beds of the Upper Limestone. The Coal Measures dip south-eastward at about 15°, while the limestone dips in the same direction at about 35°. Through Limekiln Wood to the Hatch the base of the limestone is formed by a greyish to yellow sandstone, which, in the lane at the Hatch, can be seen to overlie the basalt. The tips from the old limestone workings all along this outcrop yield a fauna indicative of the D_2 subzone[2], the forms including *Alveolites septosus* (Flem.), *Campophyllum paracida* (M'Coy), *Lithostrotion junceum* (Flem.), *L. sp.*, *Lonsdaleia floriformis floriformis* (Mart.) emend. S. Smith, and *Productus* cf. *giganteus* (Mart.).

The old quarries (Oldfield Lime Works) half a mile north-west of Little Wenlock church are now overgrown; but on the north side, 100 yds. west of the road, the basal beds of the Coal Measures can be seen to be nearly horizontal. The section shows, in descending order, (1) a concretionary ferruginous bed about a foot thick; (2) dark paper-shales, 2 ft. thick and crowded with ostracods; (3) grey carbonaceous sandstone, 7 ft. thick. At the foot of the section some blocks of pebbly coarse sandstone indicate the basal sandstone of the Coal Measures. In the fields to the south and west, on the slope above the basalt outcrop, sandstone and limestone debris is abundant.

[1] *Trans. Geol. Soc.*, ser. 2, vol. v, 1840, p. 425.
[2] See also L. M. Parsons, *Geol. Mag.*, 1919, p. 77.

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At Little Wenlock the Upper Limestone crops out in the bed of the road about 300 yds. north-east of the church, and between it and the underlying basalt, which is well exposed in the road to Horsehay, comes a well-marked bed of red bole[1], which can be seen again 100 yds. down the lane leading to Huntington. It is a tough red mudstone, breaking with a conchoidal fracture and containing relics of amygdales. The presence of this bed of bole is a strong point in favour of the extrusive character of the basalt, as it is an indication of contemporaneous weathering of the igneous rock before the deposition of the overlying limestone. The limestone crops out again, above the basalt, 400 yds. down the lane leading to Huntington.

In the old quarries at Huntington a section shows 6 ft. of sandstone on coarse conglomerate, apparently the basal bed of the Coal Measures; but the limestone is not now exposed.

East of the Little Wenlock Fault there is no definite evidence of the presence of Carboniferous Limestone over the basalt, though the tips from old shafts north of the Horsehay road contain many fragments of limestone, which may have come from below the Coal Measures and above the basalt east of the fault.

In the Buildwas road at Bragger's Hill the junction of the basalt with the overlying beds is not clear, but coal has been worked only 300 yds. to the north-east. To the east of the road the Coal Measures along the scarp by Holbrook Coppice appear to rest directly on the basalt, although at one place, 400 yds. north-west of the Moors, there are doubtful indications of an intervening band of limestone.

In Lydebrook Dingle, 300 yds. north of the Little Wenlock and Horsehay road, sandstone overlies the basalt, as is also the case in the road at Lydebrook Cottage. On the slopes of the side-valley just north of Leasows Farm there is good evidence that the Coal Measures directly overlie the igneous rock. A section about 100 yds. north of the farm-house shows about 20 ft. of Coal Measure sandstones and shales, with plant-fragments, resting on 6 ft. of red rubbly rock with much zeolitic material, which resembles in many respects a conglomerate bed at the southern end of the dingle. This rock, forming the base of the Coal Measures, appears to rest directly on the basalt. On the east side of the main dingle, north-east of the farm-house, the basalt is absent; but at the base of the Coal Measures we find about 10½ ft. of conglomerate[2], together with purple shale or bole. This conglomerate can be traced, immediately over the Lydebrook Sandstone, along this side of the dingle as far as the Stoney Hill Fault, which crosses the valley at

[1] *Cf.* H. H. Thomas, 'The Skomer Volcanic Series (Pembrokeshire),' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, pp. 183, 208; also 'The Geology of Staffa, Iona, and Western Mull' (*Mem. Geol. Surv.*), 1925, p. 62, etc.

[2] In the 'Summary of Progress' for 1924, p. 39, this was alluded to as an agglomerate, and was thought to represent the edge of the basalt; but further observations show that it is more likely to be a local conglomerate at the base of the Middle Coal Measures, derived from the waste of the basalt close by.

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the old dam of Loamhole Pool. Here the conglomerate is about 8 ft. thick. On the opposite side of the dingle, in a crag overlooking the pool, the same conglomerate, 8 ft. thick, directly overlies the Lydebrook Sandstone.

On the north-east side of the dingle, from near the waterfall (p. 147) to the Stoney Hill Fault, the conglomerate is overlain by Middle Coal Measure shales and sandstone, as is also the case, on the opposite side of the dingle, in the crags overlooking Loamhole Pool. The conglomerate itself, which is here about 8 ft. thick, is made up of blocks of decomposed basalt (E.12848), sandstone, shale, etc., in a zeolitic matrix. The blocks are more or less angular and from 6 in. to 1 ft. in diameter. The matrix contains scattered pebbles of pink quartz. At the base of the conglomerate a bed of grey shale, 3 to 6 in. thick, contains plant-remains, including *Neuropteris sp.*, thus indicating a Coal Measure age for the shale. It thus appears that the conglomerate forms the basal bed of the Middle Coal Measures, and is largely made up of debris from the basalt, which at that time must have been exposed within a few hundred yards. There can therefore be no doubt that the basalt is of earlier date than at least the local base of the Middle Coal Measures. This conglomerate has not been detected to the south-east of the Stoney Hill Fault, where the Middle Coal Measure sandstones and shales rest directly on the Lydebrook Sandstone.

At Doseley quarry a 50-ft. face of columnar basalt is capped by about 15 ft. of greenish-yellow clay, which is evidently weathered basalt, as the lines of jointing can still be detected in its lower part, while its upper part shows distinct and continuous lamination, very suggestive of deposition in water. Above this weathered material comes a bed of grey fine-grained sandstone with *Stigmaria*, which appears to be the basal bed of the Middle Coal Measures. There is no sign of a chilled upper margin to the basalt, or of any contact-alteration of the overlying sediments.

Horsehay quarry shows a 40-ft. face of massive basalt overlain by about 10 ft. of greenish serpentinous clay and ferruginous zeolitic material, the upper part of which is distinctly laminated as at Doseley, and this is followed, as at that locality, by a bed of fine-grained sandstone. This sandstone is dark grey to nearly black, and dips south-eastward at 8°. It forms the local base of the Coal Measures.

The basalt at Newdale also appears to be overlain by a bed of sandstone at the base of the Coal Measures.

The details given above show that to the north-west of the Little Wenlock Fault the basalt is overlain by the Upper Limestone, the main development of the Carboniferous Limestone of the district and referable to the D_2 subzone of Vaughan, and that this limestone is succeeded unconformably by the Middle Coal Measures. The limestone dies out at or near the fault, to the south-east of which the basalt is overlain directly by the Coal Measures. At the southern end of Lydebrook Dingle the base of the Coal Measures is

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formed by a conglomerate largely derived from the denudation of the basalt. There is no evidence that the igneous rock penetrates either the overlying Carboniferous Limestone or the Coal Measures; moreover, no signs of contact-alteration in the sediments that rest upon it have been observed.

THE BASALT OUTCROPS

At the northern end of the main outcrop near Newhouse Farm the basalt, apparently about 100 ft. thick, is compact and seldom vesicular. It is exposed in an old quarry 300 yds. east of the farm-house (E.12838). A specimen (E.12836) from 250 yds. south-east of the house is of the same type.

In the lane-section at the Hatch, where it is not more than 90 ft. thick, the igneous rock is much decomposed and highly vesicular in part, the vesicles being filled with secondary minerals.

In the northern side of a quarry about 300 yds. south of Willowmoor, large spheroidal masses of greenish-grey vesicular rock (E.13118) suggest pillow-lava. The eastern face of the quarry shows very fresh rock (E. 13119) in which the regular vertical and horizontal jointing produces blocks about the size of paving-setts. In the lane, close by the quarry, highly vesicular basalt is well exposed, but all is much decomposed; some parts of the rock (E.12837) are crowded with fragments of what appears to be the mineral chlorophaeite. There is possibly a thickness of 120 ft. of igneous rock at this locality.

Where the basalt outcrop swings to the east towards Little Wenlock it is exposed in two old quarries. In the western one the basalt is compact (E.12840), some of it showing spheroidal weathering, with suggestions of pillow-structure. In the eastern one, large pillows of compact basalt, finely vesicular throughout and 3 ft. or more in diameter, rest upon spongy lava containing large vesicles filled with secondary minerals. The space between individual pillows and between the pillows and the spongy lava below is filled with material that seems to be largely composed of fragments of chert (E.12841). A layer of reddish clay at the surface of the lower spongy lava resembles bole.

An old quarry 400 yds. south of Little Wenlock church shows a 10-ft. section of basalt (E.12842) with a tendency to spheroidal jointing. Red clay or bole is exposed at the base of the igneous rock in the lane close by, and the basalt is to be seen at several points in the lanes near the church.

In the road to Horsehay, about 400 yds. north-east of Little Wenlock church, both massive and vesicular types of basalt are fairly well exposed in the banks. As mentioned above (p. 149), the igneous rock is capped by a bed of red bole.

About 700 yds. south by west of Little Wenlock church, where the basalt forms a strong feature, it is in part amygdaloidal, but some is of a massive type (E.12843). It is exposed in the Buildwas

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road at Bragger's Hill, where it is in part vesicular, and also at various points along the north side of Holbrook Coppice, but the exposures are poor. Both vesicular and massive types occur.

Near the head of a branch of Lydebrook Dingle, about 300 yds. east by south of the Spread Eagle, Little Wenlock, dark massive basalt (E.12844) can be seen in contact with what appears to be red bole. About 100 yds. west of this point a mound of debris, apparently from an old shaft, contains large blocks of highly amygdaloidal basalt.

In the main valley (Lydebrook Dingle), at a point 270 yds. north of the Little Wenlock and Horsehay road, the stream falls over a 10-ft. bed of highly amygdaloidal and spongy lava. Owing to distortion of the steam-holes by movement of the lava before its consolidation, the amygdales are much elongated and twisted. About 100 yds. north of the road a compact dark basalt crops out in the stream-bed; while 10 yds. north of the road an exposure shows dark basalt (E.12845), somewhat vesicular and containing streaks and patches of fine material, apparently chlorophaeite, which seem to be the infilling of distorted vesicles.

South of the road the basalt is exposed in the dingle and in an old quarry 250 yds. south of the road. In a new quarry in a field on the east side of the dingle and 500 yds. south of the road the basalt seems to be made up of alternating beds of massive rock and highly amygdaloidal lava, as is also the case in a trial-trench (p. 147) cut in the side of the valley about 150 yds. south of the quarry. In this trial-trench the base of the basalt rests on the Lower Limestone, which shows signs of recrystallisation, possibly due to contact with the flow. The basalt in certain beds is a mere mass of amygdales, much distorted, and it is quite evident that originally the rock must have been an extremely spongy lava.

About 100 yds. down stream a good exposure shows over 10 ft. of similar highly amygdaloidal rock resting directly on the Lower Limestone.

In the small tributary stream 200 yds. north of Leasows Farm the basalt (E.12847) is hard and compact, but contains some vesicles and shows signs of flow. Between the basalt and the underlying Lower Limestone a bed of red ashy rock intervenes (p. 147).

In the large quarry at Horsehay the basalt is exposed to a depth of 50 ft. The main mass is compact and fresh (E.12851) and shows curious jointing and both horizontal and vertical veins (E.13120), with anastomosing veinlets. The filling of the edges of the veins consists of fibrous and satiny calcite with the fibres placed endwise to the walls of the vein and extending inwards about a quarter of an inch. The middle of the vein is made up of a mass of black shreds of what appears to be chlorophaeite, cemented together with fibrous calcite and a little quartz. The walls of the vein are fractured to a depth of an eighth of an inch or more. The fractures run obliquely to the wall, and they also are filled with fibrous calcite.

The explanation of this peculiar veining seems to be that the

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Curved joining in columnar basalt, Basalt Quarry, Doseley, Coalbrookdale.

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basalt, during cooling immediately after consolidation, was broken by numerous fissures, in which fragments, flaked off from the sides of the fissure, remained free. Subsequent crystallisation of fibrous calcite commenced on the walls of the vein and pushed to the middle of the fissure all flakes of basalt that were sufficiently loose. The interstices between these flakes then became filled with the same fibrous calcite, together with a certain amount of quartz. Towards the middle of the vein the flakes themselves have been replaced by chlorophaeite, with complete obliteration of the original basalt structure. In this quarry the base of the basalt is said to be a green serpentinous rock on green clay.

The upper part of the solid basalt is vesicular (E.12852) and shows the commencement of spheroidal weathering. Above the solid rock follows a bed, about 6 ft. thick, of decomposed basalt in the form of green serpentinous clay with fibrous calcite and ferruginous seams, with traces of spheroidal structure. Above this weathered material lies a bed, about 2 ft. thick, of what appears to be red bole, highly ferruginous and with zeolitic minerals filling cavities (E.12850). This bed is covered by about 2 ft. of ochreous yellow and grey shaly clay, upon which rest about 3 ft. of fine-grained grey Coal Measure sandstone, very dark brownish-grey in places. Sandy clay drift forms the top of the section.

At Doseley the large quarry shows fine examples of columnar jointing in a 50-ft. face. In the north-eastern face the columns are nearly vertical, but to the south-west they incline inwards towards the middle of the quarry until in the south-west face they lie endwise to the quarry face (Pl. X). They show strong evidence of movement in the intensely slickensided surfaces of the joints at right angles to the length of the columns.

In the main face of the quarry, as at Horsehay, Coal Measure sandstone is seen at the top; below this, grey shale, about 2 ft. thick, rests on about 13 ft. of laminated rotten yellow and red clayey material, some resembling bole, in the lower part of which spheroidal structure can be traced, giving way downwards to the columnar structure of the main mass of the basalt (E.12853). The joints between the columns and also the transverse joints are filled in, as at Horsehay, with fibrous calcite and what looks like chlorophaeite.

The weathering, both here and at Horsehay, appears to be contemporaneous. There are no signs of chilling at the top of the basalt. The upper part of the igneous rock is highly vesicular, and the lamination of the upper part of the weathered portion suggests a certain amount of distribution in water before the deposition of the Coal Measure sandstone.

The basalt (E.12846) outcrop at Saplins Farm, at one time quarried on a small scale, is apparently an outlying mass of very limited extent. The exposures lie from 200 to 300 yds. east-south-east of the house.

There appears to be no evidence that the basalt extends to the

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east of the Lightmoor Fault, although the Horizontal Section (*Geol. Surv.*), Sheet 54, No. 1 shows such an extension. At Lincoln Hill and in Coalbrookdale, as also in the shafts at the Meadow Pits, Madeley, and at Lightmoor Whimsey Pit, the Coal Measures certainly rest directly on Silurian rocks.

It is possible that in Lower Carboniferous times the outcrop of the Wenlock Limestone may have proved a barrier to the flow of the basalt in an eastward direction.

Dr. H. H. Thomas contributes the following petrological description of the igneous rock:—

Petrology.—All over its extensive outcrop this rock preserves remarkable constancy of petrological type and microscopic structure. Such variations as occur are either superimposed, and clearly attributable to normal processes of decomposition, or are connected with the presence or absence of vesicular structure.

In the thickest and freshest portion of the flow, well removed from the highly vesicular surfaces, the rock is of a dark grey colour and a compact, finely crystalline nature. Microscopically it is a microporphyritic olivine basalt (E.12851) referable to the Dalmeny type[1].

It consists of abundant small well-formed phenocrysts of olivine in a matrix of slender felspar-laths, small granules and prisms of augite, and a fair amount of finely divided magnetite.

The felspar is a normal labradorite, and the augite is usually a non-titaniferous variety, yellowish in thin section.

Fluxion-structure is not a general feature; but in the more superficial parts of the flow where it is thickest, and also in the more attenuated portions of the flow elsewhere, there is a pronounced parallel grouping of the felspar-laths (E.12847).

The rock varies considerably in colour and in the degree of its vesicularity. These variations have already been dealt with in the descriptions of field-occurrences, but it may be said here that the changes in colour are due entirely to the extent and nature of the secondary changes that have taken place in the rock, and are not connected in any way with original differences in rock-composition.

Olivine is sometimes preserved in a fresh condition (E.12851), but in the greater number of cases it occurs as pseudomorphs of mixed type, of which the components are serpentine and calcite (E.13119). In other instances a material, to which the name chlorophaeite has been applied, enters into the substance of the pseudomorph and has also migrated to other portions of the rock-mass (E.12853). A remarkable greenish-blue pseudomorph after olivine, composed of a highly birefringent and pleochroic mineral aggregate, occurs occasionally (E.13118).

Augite is frequently met with in an unaltered condition, but in

[1] 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), ed. 2, 1925, p. 178.

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the more decomposed samples has been replaced by chlorite or calcite.

The felspar usually show signs of alteration. In some instances there is evidence of albitization and in others of silicification or replacement by carbonates.

The rock as a whole has suffered considerable decomposition and change, but without the destruction of the original microstructure. Sometimes ferrugination is dominant (E.12847–8); while at other times chloritization plays a prominent part, and zeolitization with the production of analcite, can frequently be observed (E.12838, 12845).

A slight variant from the usual type is encountered at two localities: namely, at 700 yds. south by west of Little Wenlock church, and in the isolated mass of Saplins Farm. This type also is a microporphyritic olivine basalt, but is rather more basic than that already described. It is richer in olivine and augite, and contains its magnetite as abundant thin plates rather than as scattered grains. The augite is in this case markedly titaniferous, and in addition to the usual abundant prisms and grains it builds small porphyritic individuals. In this last character, as also in the size and proportion of the olivine phenocrysts, the rock approximates in type to the Carboniferous basalts (toadstones) of Derbyshire—a type that is also represented at Milton Hill (E.11431) and Goblin Combe (E.11428) amongst the Carboniferous flows of Somerset.

From petrological considerations it is possible that these two occurrences may result from a different outpouring from that of the main mass, which is clearly all of one type and presumably one flow. As in no place, however, have the two types been found in juxtaposition, their relation to each other cannot be determined. If the two types represent different flows it is most probable that these were successive, though from a stratigraphical point of view they may be regarded as practically contemporaneous.

LOWER CARBONIFEROUS VOLCANIC ROCKS IN OTHER AREAS

In the Bristol district, igneous rocks closely comparable with those of Little Wenlock occur in association with the Carboniferous Limestone Series[1]. At Goblin Combe and Woodspring both basaltic lava and ashes occur at Horizon γ between Z_2 and C_1. At the former locality the igneous series overlies Horizon γ and at the latter it underlies that horizon. At Uphill, on the same horizon, only amygdaloidal basalt occurs.

At Weston the igneous development occurs at the horizon C_1 to C_2, and therefore somewhat later than at Woodspring, Goblin

[1] Morgan, C. L., and S. H. Reynolds, 'The Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 137. Reynolds in 'Geology in the Field,' *Geol. Assoc.*, 1910, pp. 322–4; and 'Further work on the Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1917, p. 23.

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Combe, and Uphill. It consists of a mass of basalt about 40 to 45 ft. thick, overlain by limestone containing scattered ashy particles. The basalt includes numerous masses of limestone and some tuff, while the tuff includes large spheroids of basalt.

In Derbyshire two distinct lava-flows that occur in the Carboniferous Limestone Series have been mapped and studied in detail by H. H. Arnold-Bemrose[1], C. B. Wedd[2] and others. They are associated with contemporaneous tuffs. These basalts, like those at Little Wenlock, are in part highly vesicular and amygdaloidal, and in many respects the correspondence of the rocks of the two areas is strongly marked. The horizon at which the Derbyshire flows occurred is somewhat lower than that of the Little Wenlock flow. The lower lava is about 160 ft. down in the D_1 subzone, while the upper lava is at or near the top of that subzone[3].

SUMMARY AND CONCLUSION

The igneous rock of Little Wenlock is a microporphyritic olivine basalt of Dalmeny type, and covers a known area of about 6½ square miles east of the Wrekin.

The basalt occurs in the Carboniferous Limestone Series and maintains a constant horizon low down in the *Lonsdaleia* (D_2) subzone of Vaughan.

Along its western outcrop the rock is about 100 ft. in thickness. To the east the large quarries at Doseley and Horsehay show sections of upwards of 50 ft. of basalt, but the base is not exposed and the top has suffered denudation. The columnar structure seen at Doseley suggests that the rock was originally thickest in that area.

The evidence of denudation of the top of the basalt before the deposition of the Middle Coal Measures, especially the presence of rolled blocks of the igneous rock in a basal conglomerate of these measures, proves that the basalt is of earlier date than the Middle Coal Measures.

The complete absence of anything in the nature of chilled margins to the basalt and of metamorphic effects in the adjacent sediments, taken in conjunction with the extremely slaggy surfaces, the local tendency to pillow-structure, the association with beds of bole and the maintenance of a definite horizon in the Carboniferous Limestone Series, proves conclusively the extrusive character of the mass.

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[1] 'The Toadstones of Derbyshire: their Field-Relations and Petrography,' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 241.

[2] *In* 'The Geology of the Northern Part of the Derbyshire Coalfield' (*Mem. Geol. Surv.*), 1913, p. 22.

[3] Sibly, T. F., 'The Faunal Succession in the Carboniferous Limestone (Upper Avonian) of the Midland Area,' *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 34.

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APPENDIX II

The Lower part of the Carboniferous Limestone Series (with the Thirlwell Coal) in the Brampton and Gilsland Districts

By F. M. Trotter, M.Sc.

Text-figure 16.

The Upper and Middle Limestone Groups of the Brampton Sheet[1] (18) differ but slightly from beds of similar age in Northumberland (Fig. 6) and in the Westmorland Pennines. The beds at lower horizons, however, have not been described hitherto. The lithological succession differs markedly in these three areas, and it is now possible to establish the faunal succession in the Brampton area on the lines initiated by Vaughan[2] and Prof. E. J. Garwood.[3] The sequence determined by field mapping in the Naworth district is further strengthened by correlation with two deep bores situated respectively 7 and 9 miles to the E.N.E., which were put down to prove the Thirlwell Coal, exploited at the present time by the Mickley Coal Co. at Thirlwell Colliery near Gilsland. The horizon of the coal is now fixed and it is possible to note its lateral variations.

The lowest beds in the Carboniferous Limestone Series re-examined to date are in the Seminula Zone, some 2,000 ft. below the *Girvanella* limestone at the base of D_2, the generally accepted base of the 'Yoredales,' and apparently also below the local base of the Limestone Series a few miles farther south in the Castle Carrock and Croglin district.

Although below the *Girvanella* horizon, the type of sedimentation is 'Yoredalian' throughout, and the rhythmic succession noted by R. G. Hudson[4] in the Yoredales of Wensleydale generally applies, with, however, several exceptions.

Local names have been given to the chief limestones, which are dark grey in colour and similar in type to those of the overlying Yoredales. They are crinoidal and contain a coral-brachiopod fauna[5] in which brachiopods are most in evidence. The thinner limestones change laterally whilst the more massive ones are inconstant in thickness. The limestones are stained red and secondarily dolomitized near the Triassic overlap in the west. The sandstones, which are usually micaceous, are impersistent,

[1] *See* 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, pp. 71–4; and, 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 76–8.

[2] 'The Palaeontological Sequence in the Carboniferous Limestone of the Bristol Area,' *Quart. Journ. Geol. Soc.*, vol. lxi, 1905, pp. 181–307.

[3] The Lower Carboniferous Succession in the North-West of England,' *Quart. Journ. Geol. Soc.*, vol. lxviii, 1912, pp. 449–586.

[4] 'On the Rhythmic Succession of the Yoredale Series in Wensleydale,' *Proc. Yorks. Geol. Soc.*, New Series, vol. xx, pt. 1 (1923–24), 1924, pp. 125-135.

[5] The majority of the fossil identifications have been confirmed by Mr. J. Pringle.

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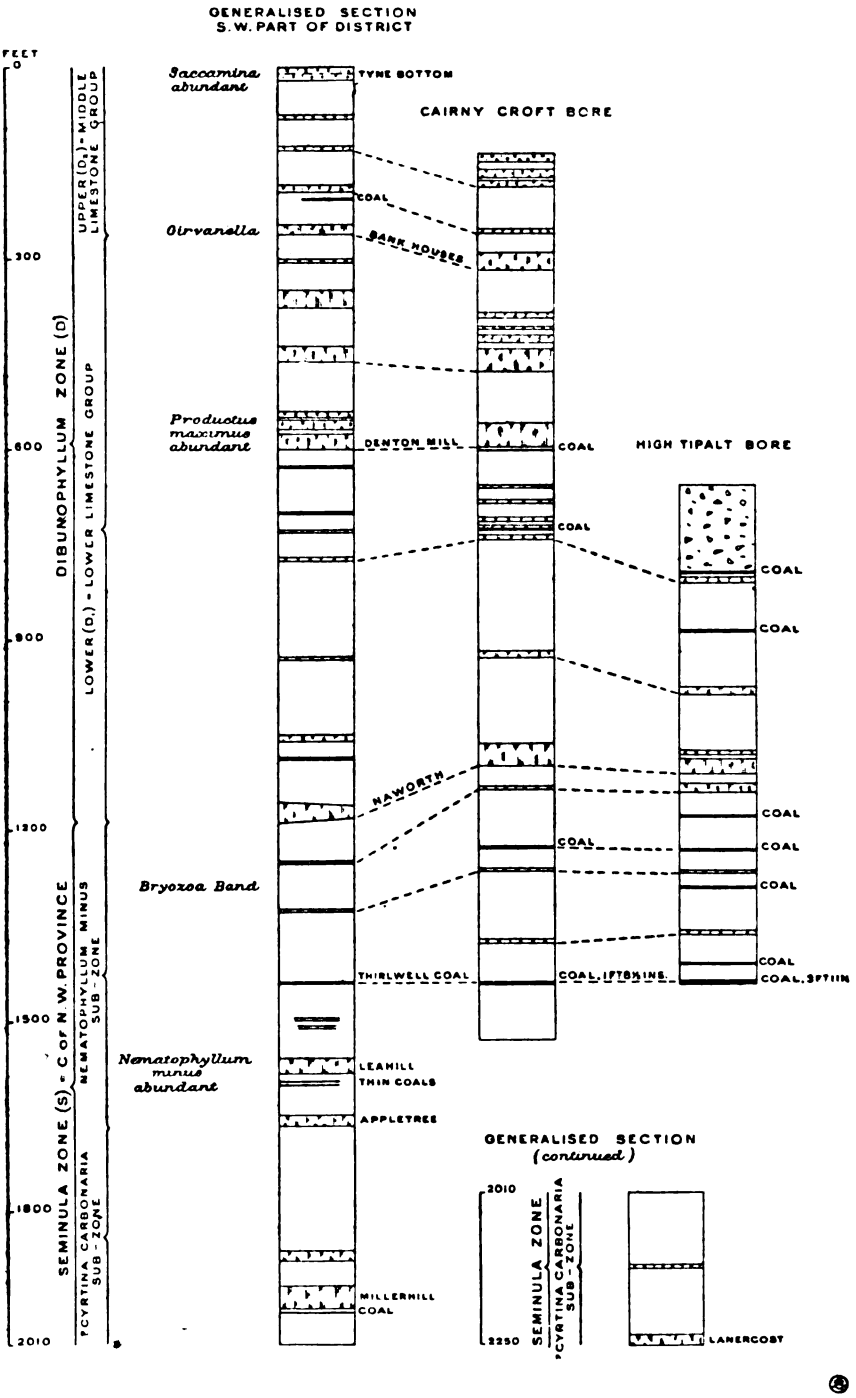

FIG. 16.—*Vertical sections in the lower part of the Carboniferous Limestone Series of the Brampton-Gilsland district.*

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and in many places pass laterally into 'grey beds.' Fossiliferous shales at several horizons yield the 'normal shale fauna' of Mr. Hudson.

Seminula Zone (below *Nematophyllum minus* Sub-zone).—No distinctive fauna has been found in the Lanercost Limestone, the lowest bed exposed in the district surveyed, but the shaly sandstone immediately above[1] has yielded *Modiola*, and at a still higher horizon shales have yielded a 'normal shale fauna' with *Modiola*, *Myalina*, more than one genus of the Pectinids, small Productids and *Lingula*.

The Millerhill Limestone (30–35 ft.) lies about 300 ft. above the Lanercost Limestone, and is underlain by a persistent coal 2 in. thick, which has been found in exposures 3 miles apart. It was recorded by G. Tate as 2 ft. at Banks[2], and this thickness has been quoted by Dr. S. Smith[3]. The coal at Banks, however, is 2 in. thick, hence it is possible that 2 ft. is a misprint for 2 in. The limestone contains *Lithostrotion martini* Ed. & H., *Productus corrugato-hemisphericus* Vaughan, and *Syringopora* in abundance. *Caninia* and *P.* cf. *corrugatus* M'Coy are also present. A 15-ft. limestone 50 ft. higher in the sequence yields a similar fauna, and although the index fossil is wanting the abundance of *P. corrugato-hemisphericus* Vaughan and *Lithostrotion martini* Ed. & H. and the absence of *Lithostrotion* (*Nematophyllum*) *minus* M'Coy suggest that these two limestones belong to the *Cyrtina carbonaria* Sub-zone of Garwood[4]. Thick sandstones account for the greater part of the 250 ft. of overlying strata.

Nematophyllum minus Sub-zone.—The Appletree Limestone (12–18 ft.) contains few fossils, but *Lithostrotion* (*Nematophyllum*) *minus* M'Coy here makes its first appearance. A sandy shale a few feet below this limestone has yielded *Lingula*. The beds between the Appletree and Leahill limestones are 30 ft. in thickness near Naworth Castle, but farther east swell out to at least 120 ft., and two thin coals underlie the higher limestone. The Leahill Limestone (25 ft.) is divided into posts by thin shale partings. It is highly fossiliferous with reefs of *Lithostrotion* (*Nematophyllum*) *minus* M'Coy and *Syringopora* throughout, whilst *Productus corrugato-hemisphericus* Vaughan is found in abundance in the shale partings. *Lithostrotion phillipsi* Ed. & H., *P. corrugatus* M'Coy, *Aulopora* and *Caninia* are present also.

The Thirlwell Coal lies about 150 ft. above the Leahill Limestone and some 250 ft. of strata, including two thin limestones, separate the coal and the Naworth Limestone. The coal crops

[1] Fossil horizons discovered by Mr. A. Templeman.

[2] 'The Geology of the District traversed by the Roman Wall' in 'The Roman Wall: a description of the Mural Barrier of the North of England' by J. Collingwood Bruce, ed. 3, 1867, Newcastle-upon-Tyne, p. 441.

[3] 'Report. . . . .on the Carboniferous Limestone Formation of the North of England,' *N. of Eng. Inst. Min. and Mech. Eng.*, 1912, Newcastle-upon-Tyne, p. 75.

[4] *Op. cit.*, pp. 470–1.

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out in the River Irthing opposite Lanerton, where it is only 5 in. in thickness. A shale between these two limestones has yielded a prolific fauna of Bryozoa, lamellibranchs, brachiopods, trilobites and a goniatite. The horizon may be correlated with Garwood's 'Bryozoa Band' at the top of the *Nematophyllum minus* Sub-zone[1].

Lower Dibunophyllum Sub-zone (Lower Limestone Group).—*Lithostrotion* (*Nematophyllum*) *minus* M'Coy ranges upward into the Naworth Limestone, but nevertheless the latter has been taken as the base of D_1, because this limestone overlies the Bryozoa Band, and because the 500 ft. of still higher strata contain but thin limestones which cannot be traced far. The Naworth Limestone varies in thickness, with a minimum of 12 ft. It yields *Lithostrotion junceum* (Flem.), large form, *L.* (*Nematophyllum*) *minus* M'Coy, *Syringopora*, *Productus* cf. *corrugatus* M'Coy and *P.* cf. *maximus* M'Coy.

The succeeding strata for some 500 ft. include thin limestones which have yielded *Productus* cf. *maximus* M'Coy.

The Denton Mill Limestone (34 ft.) yields a typical D_1 fauna including *P. maximus* M'Coy and *Chonetes comoides* (J. Sow.). No continuous section is available between the Denton Mill and the Bankhouses Limestone about 250 ft. higher, but the beds include at least three limestones.

Upper Dibunophyllum Sub-zone, D_2 (Middle Limestone Group).—Occasional nodules of *Girvanella* are found encrusting crinoid stems in the Bankhouses Limestone which is taken as the base of D_2. Beds about 300 ft. in thickness, including three limestones, separate the Bankhouses from the Tyne Bottom Limestone. The latter yields *Saccammina carteri* Brady.

Correlation.—The thick Melmerby Scar Limestone of the Westmorland Pennines represents the D_1 Sub-zone and the upper part of the *Nematophyllum minus* Sub-zone[2]. Faunal comparison with the beds in the Brampton district shows that this mass of almost continuous limestone is split up by sandstone and shales into a number of limestones, evidently indicating that the Brampton area was nearer land. This is particularly interesting because deposits of this latter area were being formed under similar conditions whilst the conglomerates underlying the Melmerby Scar Limestone were being deposited close to a shore line. The North Northumberland and East Cumberland sequences are compared in Fig. 6, p. 81, and it appears that the fresh-water series of Scremerston is represented in the Brampton area by marine deposits. The series in the latter district still contains coals, but only one —the Thirlwell seam—is of workable thickness. The Scremerston Coal Group appears to be equivalent to the lower part of the Lower

[1] *Op. cit.*, pp. 473–4.
[2] Garwood, E. J., *op. cit.*, p. 493.

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Dibunophyllum Sub-zone and part, if not all, of the Seminula Zone.

The Thirlwell Coal.—Some of the characteristics of this coal have been described by Dr. S. Smith[1], note may be made however of its bad roof of soft shale at Thirlwell Colliery. The coal lies between the Naworth and Leahill limestones and falls within the limits of the *Nematophyllum minus* Sub-zone. The coal is 3 ft. 4 in. to 3 ft. 9 in. thick at Thirlwell Colliery, and in a distance of 3½ miles to the south-west it has deteriorated to a 5-in. coal. Figure 16 shows that many of the coals recorded in the High Tipalt boring[2] are dying out in this direction.

The Cairny Croft boring is one mile south of the outcrop of the Thirlwell Coal. It commenced above the second limestone below the Tyne Bottom Limestone and proved the coal, only 1 ft. 8½ in. in thickness, at a depth of 1,353 ft. This appears to indicate a southward thinning. The High Tipalt boring, three miles to the east of Thirlwell Colliery, records the coal, 3 ft. 1 in. in thickness, at a depth of 805 ft. 10 in.: considerable reserves may be anticipated eastward from the Thirlwell workings.

[1] *Op. cit.*, p. 144.
[2] Published by S. Smith, *op. cit.*, pp. 145–6.

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APPENDIX III

The Section of the New Railway Tunnel through the Malvern Hills at Colwall

By T. Robertson, Ph.D.

Plate XI. Text-figures 17 and 18.

A new tunnel, recently driven through the Malvern Hills by the Great Western Railway Co., has afforded an opportunity for obtaining additional information regarding the structure of the range. The old tunnel, which was made about the middle of last century, was kept under observation by W. S. Symonds and A. Lambert[1]. The new one is on the south side of the old, the distance between their mid-lines being only 44 ft., and the sections are similar in all essential points. Observations in every case were taken in the heading driven in advance of the tunnel, and, unless otherwise indicated, refer to the rail-level in the middle line of the tunnel as completed. The chief points of interest are shown on the accompanying map and section (Figs. 17 and 18), and will be dealt with in order from east to west, beginning with the cutting at the eastern end. All measurements in the tunnel are from its eastern mouth.

Keuper Marl.—This formation occupies the eastern cutting and the tunnel to 505 ft. At the tunnel mouth the cutting is between 80 and 100 ft. deep, and gave a good section of brownish-red marl with greyish-green skerries. The line of the tunnel is approximately at right angles to the strike of the beds, and the green bands reveal the structure as a gentle anticline, broken in three places by small faults with throws varying from 5 to 15 ft., the downthrow in each case being towards the hill, *i.e.*, westward. The most conspicuous zone in the cutting lies about half-way up the slope towards the east end, but it is faulted down out of sight at the tunnel mouth. It showed the following section:—

	Ft.	in.
Reddish-brown marl	–	–
White gypsum		2 to 3
Mottled green and red sandy marl	1	0
Brown fine-grained sandstone with ' fish-eyes ' and sporadic small rounded grains of quartz	0	9
Mottled green and reddish-brown sandy marl, the lower greenish part in some places being a definite sandstone band	1	0
Reddish-brown marl, about	2	0
Green band, with a well-defined round-grained sandy layer, about		3 to 6
Reddish-brown marl	–	–

This zone is clearly seen on the left-hand side of the photograph (Plate XI). The 'fish-eyes' in many cases contain small carbonaceous centres.

[1] *Quart. Journ. Geol. Soc.*, vol. xvii, 1861, p. 152.

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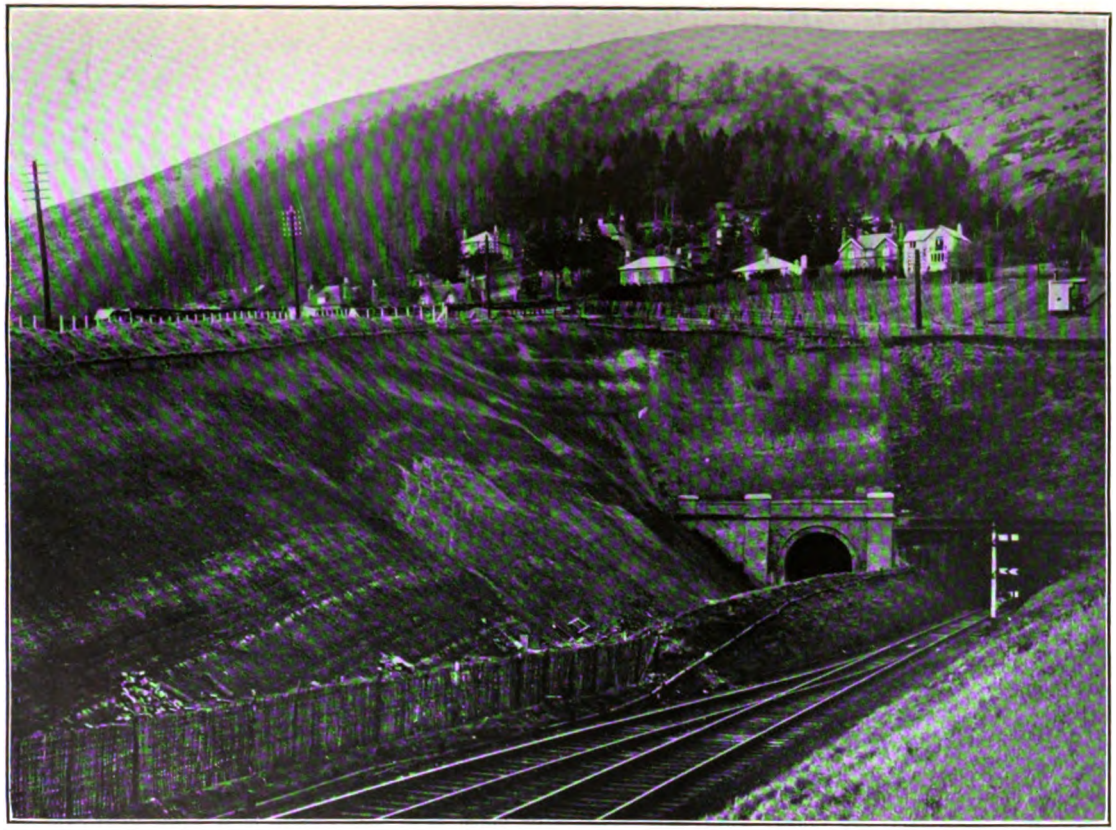

General view of cutting at east end of the new tunnel, Colwall.

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At the mouth of the tunnel the beds flatten and a synclinal axis is crossed at 40 ft. inward. Near here, and indeed throughout the Keuper zone in the tunnel, there are numerous slips of at most a few feet in throw, all of them throwing down towards the Archaean. The bedding is shown chiefly by the greenish bands. Beyond the synclinal axis the beds rise, attaining a maximum eastward dip of about 45° at 170 ft., after which they flatten again westward towards an anticlinal axis at about 450 ft. Beyond this there is a fault at 475 ft., throwing down the beds about 8 ft. westward. For the next 20 ft. the dip is westward at a low angle, and then at 495 ft. the marls rise sharply at 45° along the face of the Archaean boundary-fault.

The total thickness of Keuper beds traversed is about 200 ft. There is no appreciable increase of arenaceous material downwards, such as would indicate an approach to the Lower Keuper Sandstone, so that all must be considered to belong to the Marl subdivision. A 2-ft. band of soft grey sandstone occurs at 340 ft., but this was the only conspicuous sandstone band seen in the sequence apart from those in the cutting. It appears to be dolomitic and contains scattered 'millet-seed' grains of quartz. Some of the red marls show similar grains.

Keuper and Archaean Junction.—This extends from 505 to 525 ft. On the Keuper side it is a clean-cut fault, coursing northward at an angle of 80° to the line of the tunnel and dipping eastward at 45°. At 495 ft. the Keuper beds suddenly tilt up parallel to the fault-plane, but are not broken till within about a foot of the fault. Then follow 20 ft. of breccia, composed of Archaean fragments, up to about 3 in. in diameter, embedded in a marly matrix. No other rock was seen. The breccia is uncemented, in contrast with that to be seen in the quarries at North Malvern, where it forms a hard cake adhering to the unbrecciated Archaean. The breccia in the tunnel passes gradually westward into somewhat less disturbed Archaean, but the rock is much broken for a considerable distance. The surface evidence is confirmatory. The approximate position of the fault can be located with ease from the topography, and shows that the general dip of the fault-plane is not much steeper than that of the section shown in the tunnel, namely 45° to 50°. On the hill the exposures of Archaean near the fault are also invariably much broken in this portion of the range.

Archaean.—This occupies the tunnel from 525 to 2,175 ft. At 540 ft. the rocks are still much shattered, not only in hand-specimens, but also microscopically. West of this as far as about 750 ft. they are much broken in hand-specimens and stained considerably with iron, but are not pulverized. In this portion of the section the rocks are chiefly epidioritic in character, as shown by specimens at 640 and 740 ft., which are respectively coarse and fine in grain. Owing to the fracturing there is practically no

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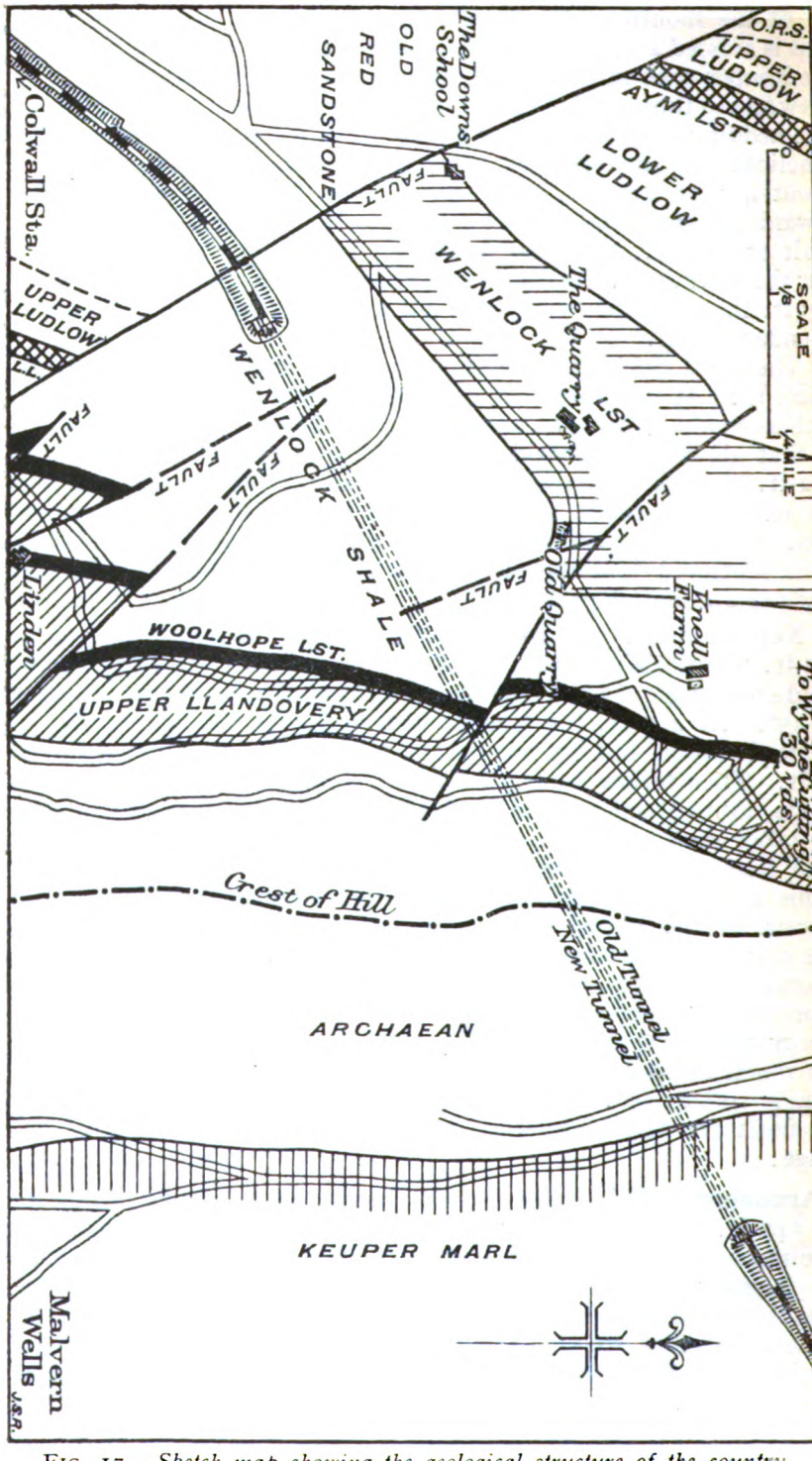

FIG. 17.—*Sketch map showing the geological structure of the country near Colwall and Malvern Wells.*

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indication of the direction of the planes of foliation, and there are many slip-planes faced with green or red clay, in every case dipping eastward. At 810 ft. a cavity lined with barytes appears still to indicate connexion with the Triassic rocks on the east, but west of this no trace of their influence has been seen. At about 880 ft. the rock is very hard, and thence to 960 ft. it is still epidioritic in general. A soft grey schist, dipping south-eastward at 75°, passed through from 960 to 970 ft., contains near its eastern side a graphitic zone, but no pure graphite was found. Thence to 1,100 ft. follow alternating bands of green to grey schist and quartzo-felspathic gneissic rock. In this section there are apparently many crush-zones. In every case the schists dip eastward at a high angle. At 1,105 ft. a well-defined shear-plane, dipping eastward at 20° and containing much clay, introduces a belt of shearing that extends to 1,170 ft., the rocks being similar to those immediately to the east. Then follows a green epidiorite veined with pink quartzo-felspathic material to 1,211 ft.; a sheared zone, chiefly of green schist, to 1,236 ft.; and a belt with much coarse pegmatitic veining to 1,245 ft., where a specimen obtained is a granitoid biotite-gneiss. From here onwards the rock is tough and very hard, with no regular jointing. It is generally a fine-grained epidiorite, quite basaltic in appearance, but showing distinct banding in hand-specimens and in places schistosity. The gneissic banding is shown up chiefly by pink quartzo-felspathic lenticles, the distinct veins of such material seen farther east being quite rare. From about 1,300 to 1,700 ft. the dip of the foliation planes is southward at 60° to 70°. One band at 1,280 ft. is distinctly a mica-schist. At 1,410 ft. a sheared zone coursing north-eastward crosses the tunnel. For the next 100 ft. much calcite veining is noticeable, and the more schistose zones in this section are hornblende schists, *e.g.*, at 1,480 ft., with a tendency towards granulitization. A coarse patch at 1,496 ft. is a granitoid hornblende-gneiss. Westward the foliation becomes less distinct, but patches with much red pegmatitic veining occur at intervals. These conditions continue to 1,865 ft., when a broken zone, 15 ft. wide, of Silurian rock suddenly appears. It consists of crushed calcareous mudstone similar to the Llandovery beds just west of the Archaean. It was in this fault-zone that Llandovery shells were found in the old tunnel. West of the broken zone the rock is a hornblende-schist with red felspathic veins and bands, the foliation planes still dipping steeply southward. Beyond 2,100 ft. it is distinctly granulitic in many places, as is shown by a specimen from 2,110 ft. Just east of the fault that brings in the main zone of Llandovery the Archaean is almost unbroken. The dip of the foliation swings round until at 2,150 ft. it is vertical and at right angles to the line of the tunnel.

The rail-level of the tunnel being about 600 ft. vertically below the crest of the range, it was not to be expected that any close correspondence would be found between the rocks at the surface

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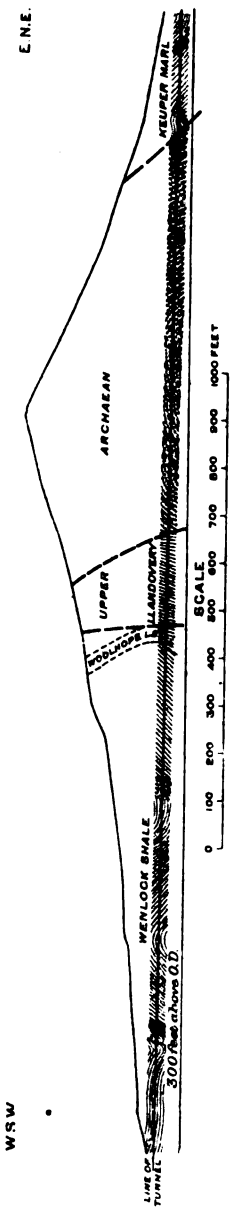

FIG. 18.—*Transverse section of the Malvern Range along the line of the new Colwall Tunnel.*

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and those in the tunnel. On the hill there is no indication of the hard epidiorite that forms its core, the chief rock on this portion of the range being a quartzose mica-schist or granulite. Just north of the line of the tunnel the direction of foliation in these rocks corresponds to that found underground; but on and immediately south of the line the strike of the foliation is north-north-east and south-south-west. On the ridge, 120 yds. south of the line, an outcrop of epidiorite, 20 yds. wide, appears in the form of a dyke, coursing north-eastward and nearly vertical. No later dykes, like those coursing northward on the western side of the Worcestershire Beacon, were found in the tunnel.

Archaean and Upper Llandovery Junction.—This is situated between 2,175 and 2,185 ft. Even within a few feet of the fault that separates the Archaean from the Llandovery the former is not appreciably broken, and the fault itself is vertical, coursing northward at an angle of 45° to the line of the tunnel. In the old tunnel also the junction is practically vertical. The Llandovery rocks, which are more or less calcareous mudstones, stand vertically, and are broken, but not violently crushed, for about 10 ft. from the junction, beyond which they are not much affected. The small amount of disturbance is noteworthy. The surface position of the fault, which, although not actually visible, can be located within 15 yds., lies 200 to 250 ft. farther west along the line of the tunnel. This gives a dip for the fault of 75° to 80°, or a reversed hade of 10° to 15°. Farther north an inclusion of Llandovery in the Archaean at the western end of the Wyche cutting is within 15 yds. of the Llandovery belt to the west, and so is best regarded as within the fault zone, especially as the Archaean that was exposed west of it was all much broken[1].

Upper Llandovery.—This formation lies between 2,185 and 2,560 ft. From 2,185 to 2,250 ft. these beds are vertical, the direction of strike being inclined at an angle of 30° to the line of the tunnel. Then follows a somewhat sheared belt, 20 ft. thick, of grey calcareous shales with shelly bands, beyond which the beds dip westward at about 80°, coming down to 65° at 2,535 ft. The total thickness of the Llandovery beds passed through is about 250 ft. The strata throughout consist of flaggy calcareous and sandy mudstones, grey to purple in colour, mottled with brown. Sandstone bands, not common in any part, are almost absent near the top. In many places shelly bands, chiefly showing small brachiopods, were seen, and specimens of *Pentamerus oblongus* J. de C. Sow. and *Stricklandinia lens* (J. de C. Sow.) were also found.

On the surface the outcrop of the Llandovery beds is marked by a belt of yellowish-grey clayey ground parallel to the Archaean boundary-fault, and fragments of the harder sandy layers are usually to be seen. In the vicinity of the tunnel the beds are in every case inverted, dipping eastward at about 45° (*i.e.*, the true

[1] Phillips, J., *Mem. Geol. Surv.*, vol. ii, pt. 1, 1848, p. 64.

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dip being west at 135°). As no graptolites have yet been found in these rocks it is not possible to say whether any representative of the Tarannon group is present. Between Colwall and West Malvern the Llandovery beds are about 250 ft. thick; but farther north some pink grits lower in the series appear. In this connexion the problem of 'Miss Phillips's Conglomerate' is still unsolved[1]. In an exposure on the flank of the hill behind the houses about 220 yds. south-east of St. James's Church, West Malvern, it clearly lies unconformably upon and contains pebbles of the Archaean. About 300 yds. farther south, however, the boundary-fault is to be seen at the foot of the Dingle, and as it can hardly have died out in the intervening ground it presumably lies to the west of the conglomerate exposure. This leaves uncertain how the conglomerate is related to the pink grits of Rough Hill. At the exposures mentioned the conglomerate yielded specimens of *'Petraia' bina* (Lonsd.), *Camarotoechia borealis* (Schloth.), *Orthis calligramma* Dalm., and *Spirifer elevatus* (Dalm.). Phillips[2] mentions also "*Favosites multipora*, *Orthis bilobata*, and *O. flabellulum*."

Woolhope Limestone.—This extends from 2,560 to 2,655 ft. The dip of these beds is westward at 65° and the direction of strike is inclined at an angle of 45° to the line of the tunnel. This indicates a thickness of about 55 ft. The eastern junction with the Upper Llandovery is, however, a fault, which can be traced at the surface, where, along the line of the tunnel, it appears to cut out between 50 and 100 ft. of the top beds of the Llandovery. These highest beds are in part flaggy sandstones, as can be seen in several exposures, and the absence of strictly comparable beds in the tunnel makes it probable that they are cut out by the fault there as well as on the surface. Bands with large specimens of *Pentamerus oblongus* were found just at the base of the limestone, but to which side of the fault they belong is uncertain. The limestone itself is flaggy and argillaceous, with bands of corals and crinoids. A clay band, below which is a crinoidal and shelly limestone and above which the beds become distinctly more argillaceous, is taken as indicating the top of the Woolhope Limestone in the section.

On the surface the limestone forms a distinct feature. Along its outcrop it is inverted; in the tunnel it dips normally. The limestone bands of which it is composed are brownish in colour and have a somewhat cavernous type of weathering, which is characteristic. Where exposed on the path leading from the Wyche cutting to Knell Farm it consists of a series of thin limestone bands, none more than 6 in. thick, in grey shales. The most conspicuous feature among these beds is a coralline band near the top of the sequence. Many of the argillaceous bands are full of crinoid frag-

[1] Phillips, *op. cit.*, pp. 66–9.
[2] *Op. cit.*, p. 69.

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ments. The following fossils were obtained at this locality and in the bridle-path a short distance farther south:—

Halysites catenularia (*Linn.*)
Ptychophyllum patellatum (*Schloth.*)
Small solitary corals
Crinoid stems and fragments
Atrypa imbricata (*J. de C. Sow.*)
,, reticularis (*Linn.*)
,, sp. (small)
Meristina sp.
Orthis (Dalmanella) elegantula *Dalm.*
Orthis (Dalmanella) sp.
,, (Bilobites) biloba *Linn.*
Plectambonites transversalis (*Dalm.*)
,, sp.
Stropheodonta filosa (*J. de C. Sow.*)
,, sp.
Illaenus barriensis (*Murch.*)
Phacops sp.

Wenlock Shale.—This runs from 2,655 ft. to the western mouth of the tunnel at 4,760 ft. and occupies the western cutting to 220 ft. from the mouth. The formation is arranged in several approximately symmetrical folds pitching northward at an angle of about 30°. Several fractures coursing in a north-north-westward direction and so somewhat transverse to the axial direction of the folds, occur chiefly near the synclinal axes. These make an accurate estimate of thickness impossible. The synclinal axes lie at 3,450 and 4,340 ft., with an intermediate anticlinal axis at 3,890 ft. At a rough estimate the beds traversed in the tunnel represent the lowest 450 ft. of the group, or about half of its total thickness. Another 50 ft. are shown in the cutting at the western end, leaving about 300 ft. at the top not exposed.

In character the beds vary very little. They are greyish-blue mudstones, with a purplish tint in some zones, and with occasional limy and fossiliferous bands. The bedding is not usually well marked, but bands of grey clay, 1 to 2 in. thick, show it up at intervals. A belt of broken ground from 3,170 to 3,295 ft. falls into line with a fault to be seen in the Wenlock Limestone in a quarry 200 yds. east of a house called the Quarry. Another broken belt coincides with the axis of the syncline that was crossed at 3,450 ft. The anticlinal axis at 3,890 ft. is only slightly broken. From 4,230 to 4,280 ft., and again from 4,315 to 4,360 ft., there are badly faulted zones, the latter including the more western synclinal axis. These zones are in obvious continuity with two faults seen on the surface, converging north-westward, one on each side of Linden. The angles of dip observed in the tunnel reach a maximum of about 60° in the unbroken zones, but as allowance must be made for the pitch of the folds, the folding itself is seen to be only moderate in amplitude, with a maximum of 45° tilt of the limbs.

The Wenlock Shale exposed in the western cutting is similar to that in the tunnel. It dips northward at 35° and is covered by superficial material, apparently talus and weathered shale, to a thickness of from 10 to 15 ft. At 140 ft. from the mouth of the tunnel a fault, probably throwing down eastward, brings in some lavender-coloured shales. These also are Wenlock, and dip northward at 25°.

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The following list of fossils from the Wenlock Shale of Colwall is an endeavour to bring our knowledge of its fauna up to date. Owing to the method of excavation adopted at the new tunnel it was found impracticable to make any attempt to zone the formation during the progress of the work, but general observations show that the fauna varies little throughout the thickness of the group. Fossils are generally abundant, and Mr. H. F. Metcalfe's list shows a striking fact that may be of value in future work. His material from the western cutting of the old tunnel is probably from about 300 ft. below the top of the group, and is composed chiefly of brachiopods and corals; whilst that which he obtained from near the base of the group in Parkwood, about a mile farther north, consists mainly of brachiopods and trilobites. This comparative rarity of corals near the base was noted in the new tunnel also. In addition to the fossils in the list, *Cyathophyllum flexuosum* (Linn.) is recorded from the Wenlock Shale of Colwall by Milne-Edwards & Haime.[1]

Fossils from the Wenlock Shale at Colwall, Malvern Hills

1. Grindrod Collection, Oxford University Museum, by permission of Professor W. J. Sollas. Partly from the old tunnel and partly from surface exposures.
2. Dr. T. T. Groom, *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, pp. 147–8. From the cutting at the western end of the old tunnel.
3. Mr. H. F. Metcalfe, Malvern Link. In manuscript. Partly from the same locality as 2, and partly from a quarry for a light-railway embankment, Parkwood.
4. From the new Colwall Tunnel. Identifications by J. Pringle.

The fossils in the first three collections are given here without revision. Species marked with an asterisk are very common.

Ischadites koenigi *Murch.*, 1.
Receptaculites neptuni *Defr.*, 3.
Labechia conferta (*Lonsd.*), 3.
Stromatopora concentrica *Goldf.*, 3.
Aulacophyllum mitratum (*Schloth.*), 2, 3.
Cyathophyllum articulatum (*Wahl.*), 3.
,, pseudoceratites (*M'Coy*), 1.
,, truncatum (*Linn.*), 3.
Cystiphyllum cylindricum *Lonsd.*, 3.
? ,, grayi *Edw. & Haime*, 3.
*Favosites gothlandicus *Lam.*, 2, 3.
,, fibrosus ? (*Goldf.*), 2.
*Heliolites interstinctus (*Linn.*), 2, 3, 4.
,, grayi *Edw. & Haime*, 3.
*Hemiphyllum siluriensis (*M'Coy*), 3.
Monticulopora pulchella (*Edw. & Haime*), 3.
Omphyma turbinata (*Linn.*), 1.
,, subturbinata (*d'Orb.*), 3.
,, sp. [allied to *O. murchisoni* Edw. & Haime], 3.
*Palaeocyclus fletcheri *Edw. & Haime*, 2, 3.
* ,, rugosus *Edw. & Haime*, 2, 3.
*Plasmopora petaliformis (*Lonsd.*), 2, 3.
Propora tubulata (*Lonsd.*), 4.

[1] 'Brit. Foss. Corals,' *Mon. Pal. Soc.*, 1850, p. 285.

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Syringopora bifurcata *Lonsd.*, 2.
Thecia swindernana (*Goldf.*), 2.
Ateleocystites sp., 1.
Eucalyptocrinus decorus *Phill.*, 1.
Herpetocrinus fletcheri *Salt.*, 1.
Pisocrinus flagellifer *Ang.*, 1.
* ,, pilula *de Kon.*, 3.
Schizocystis armatus (*Forb.*), 1, 2, 3.
Cornulites scalariformis *Vine*, 3.
*Anastrophia deflexa (*J. de C. Sow.*), 2, 3.
*Atrypa asperula *Dav.*, 3.
* ,, barrandei (*Dav.*), 2, 3.
* ,, imbricata (*J. de C. Sow.*), 2, 3, 4.
* ,, reticularis (*Linn.*), 2, 3, 4.
*Barrandella linguifera (*J. de C. Sow.*), 2, 3.
Camarotoechia borealis (*Schloth.*), 3.
,, nucula ? (*J. de C. Sow.*), 2.
*Cyrtia exporrecta (*Wahl.*), 1, 2, 3.
*Leptaena rhomboidalis (*Wilch.*), 1, 2, 3, 4.
,, segmentum *Ang.*, 1, 3.
*Meristina tumida (*Dalm.*), 4.
Obolus davidsoni *Salt.*, 1.
Orbiculoidea morrisi (*Dav.*), 1.
Orthis (Bilobites) biloba (*Linn.*), 4.
* ,, (Dalmanella) elegantula *Dalm.*, 1, 2, 3, 4.
,, ,, sp., 4.
* ,, (Hebertella) rustica *J. de C. Sow.*, 1, 2, 3.
,, (Rhipidomella) hybrida *J. de C. Sow.*, 1, 2.
Pentamerus rotundus (*J. de C. Sow.*), 1.
Plectambonites quinquecostatus (*M'Coy*), 1.
* ,, transversalis (*Wahl.*), 2, 3, 4.
,, sp., 4.
Sieberella galeata (*Dalm.*), 2.
*Spirifer crispus (*His.*), 2.
* ,, elevatus (*Dalm.*), 3, 4.
,, plicatellus (*Linn.*), 1, 2, 3, 4.
Stropheodonta filosa (*J. de C. Sow.*), 1, 3.
,, imbrex (*Pander*), 2, 3.
,, pecten (*Linn.*), 3.
Strophomena antiquata (*J. de C. Sow.*), 1, 2, 3.
,, euglypha (*His.*), 1.
Strophonella funiculata (*M'Coy*), 2.
Wilsonia wilsoni (*Dav.*), *var.* davidsoni *M'Coy*, 1.
,, sp., 4.
Anodontopsis perovalis (*Salt.*), 1.
'Avicula' danbyi *M'Coy*, 1.
,, mira *Barr.*, 1.
Cardiola interrupta (*Brod.*), 1.
Ctenodonta sulcata *His.*, 1.
Lunulacardium sp. nov., 1.
Orthonota prora *Salt.*, 3.
,, rigida (*J. de C. Sow.*), 1.
,, solenoides (*J. de C. Sow.*), 3.
Pterinea planulata *Conr.*, 1, 3.
,, posidoniaeformis *M'Coy*, 1, 3.
'Acroculia' prototypa *Salt.*, 3.
,, euomphaloides *M'Coy*, 3.
Bellerophon acutus *J. de C. Sow.*, 1.
,, wenlockensis *J. de C. Sow.*, 1.
Eunema rupestre *Eichw.*, 1.

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Euomphalus alatus *Phill.*, 1, 3.
,, funatus *J. de C. Sow.*, 1.
,, praenuntius *Phill.*, 3.
,, sculptus *J. de C. Sow.*, 1.
Murchisonia lloydi (*J. de C. Sow.*), 1.
Lituites articulatus *J. de C. Sow.*, 1.
Orthoceras angulatum *Wahl.*, 2, 3.
* ,, annulatum *J. Sow.*, 4.
,, sp., 3.
Dalmanites caudatus (*Brünn.*), 1, 2, 4.
* ,, longicaudatus (*Murch.*), 1, 3.
,, ,, ,, *var.* grindrodiana *Salt.*, 1.
Deiphon forbesi *Barr.*, 3.
Encrinurus punctatus (*Brünn.*), 1, 2, 3.
Illaenus barriensis (*Murch.*), 1, 3.
Phacops coronatus *H. Thomas*, 1.
* ,, downingiae (*Murch.*), 2, 3.
,, ,, *var.* constrictus *Salt.*, 1.
,, ,, *var.* vulgaris *Salt.*, 1.
* ,, musheni *Salt.*, 1, 3.
,, sp., 4.
Proetus ?, 4.
Sphaerexochus mirus *Barr.*, 3.
Staurocephalus murchisoni *Barr.*, 3.

Wenlock Shale and Old Red Sandstone Junction.—At 220 ft. from the western mouth of the tunnel the lavender shales mentioned above are cut off by an almost vertical fault, which brings against them certain beds that lie probably some 300 ft. above the base of the Old Red Sandstone. Judging from the average thickness of the intervening measures present in the district[1], this indicates a throw of nearly 2,000 ft. The change of colour is very abrupt and striking, but there is much more disturbance on the Old Red side than on the Wenlock side of the fracture. The fault, which can be traced clearly on the surface, displaces the outcrop of the Aymestry Limestone by over half a mile.

Old Red Sandstone.—West of the fault the purplish-red mudstones and micaceous brown sandstones of the Ledbury Passage Beds are exposed, dipping west at an angle of 60° to 90°. The mudstones greatly predominate, and are usually mottled with green. At 600 ft. from the tunnel mouth a belt of nearly vertical sandstones is entered, crossing the cutting obliquely in a northward direction. The section is as follows:—

	Ft.
Sandstone, chocolate brown, micaceous and flaggy, becoming purplish towards the top and passing upwards into mudstones. A well-marked band about 1 ft. from the base contains fish-remains	12
Alternating soft purple micaceous sandstone and purple and mottled mudstone	15
Sandstone, grey, flaggy, coarse grained and calcareous ..	3
Reddish-brown mudstones	—
	30

[1] Groom, T. T., in 'Geology in the Field,' *Geol. Assoc.*, 1910, p. 704.

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From the fish-band Mr. W. W. King obtained specimens of *Eukeraspis*, *Cephalaspis*, and *Auchenaspis egertoni*, and he suggests that the beds should be correlated with the Ledbury Fish Zone, about 450 ft. above the Ludlow Bone Bed at Ledbury. Beyond this belt come soft mudstones for a distance of about 600 ft., where the section ends.

The close correspondence between the record given above and that left by Symonds and Lambert is noteworthy, and is a high tribute to the work of these older observers. In the present investigation help has been received from a number of sources. Through their resident engineer, Mr. H. Bromley, the Great Western Railway Co. afforded every facility for making the observations in the tunnel. Mr. A. Bennett, of Upper Colwall, not only assisted in making the observations in the tunnel, but also by his intimate knowledge of the district helped greatly in the surface-mapping. In every way, indeed, his help has been invaluable. Mr. W. Wickham, of Upper Colwall, has also assisted with his knowledge of the geology of the Malverns, and by his personal acquaintance with many of the older workers. The view reproduced herewith is the work of Mr. F. Day, of the Downs School, Colwall, who took a number of photographs of the tunnel and has lent his negatives, so that copies might be placed in the Survey collection. Mr. J. Pringle, who paid several visits to the tunnel during the investigations, has advised on the palaeontological and stratigraphical questions involved, besides examining and naming all the fossils collected.

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APPENDIX IV

A Pit Sinking in County Durham

By G. A. Burnett, B.Sc.

In 1923–1925 two new shafts were sunk at Annfield Plain by the Holmside and South Moor Collieries Ltd. Situated in the heart of the Durham coal-field, these shafts provide a clear and typical section through most of the Lower Coal Measures, down to the bottom seam, the Brockwell Coal. Mr. T. Y. Greener, agent to the Company, kindly gave Mr. Burnett every facility in examining the strata cut through. An abstract section of the sinking is as follows:—

	Thickness Ft.	in.	Depth Ft.	in.
Boulder Clay	26	11	26	11
Sandstone	32	9	59	8
Grey post	3	6	63	2
Coal (old waste) **Shield Row**	**4**	**8**	**67**	**10**
Seggar clay	–	8	68	6
Blue and black shale	33	2	101	8
Alternating blue-grey shale and grey post	70	10	172	6
Coal. **Five Quarter**	**3**	**4**	**175**	**10**
Band	–	5	176	3
Coal. **Main**	**2**	**10**	**179**	**1**
Seggar	4	0	183	1
Grey and white post	7	0	190	1
Grey or blue shale with sandstone ribs	37	9	227	10
Grey and white post	15	6	243	4
Black shale	–	5	243	9
Coal	–	1	243	10
Tough black mudstone	–	5	244	3
Coal	–	4	244	7
Shale and coal partings	2	0	246	7
Grey and blue shale	9	7	256	2
White post	13	9	269	11
Grey shale	–	6	270	5
White post	45	4	315	9
Grey and blue shale	3	6	319	3
Grey post	20	11	340	2
Blue shale	6	0	346	2
Coal (old waste). **Maudlin**	**3**	**3**	**349**	**5**
Band	2	3	351	8
Coal (partly old waste)	**3**	**9**	**355**	**5**
Band **Low Main**	–	9	356	2
Coal (old waste)	**1**	**1**	**357**	**3**
Sandy fireclay	1	4	358	7
Grey sandy shale	25	5	384	0
Coal (partly old waste). **Hutton**	**3**	**6**	**387**	**6**
Black parroty shale	–	6	388	0
Fireclay	2	6	390	6
Blue and grey metal	46	10	437	4
Grey and blue metal with leafy posts	64	11	502	3
Ironstone girdle	1	3	503	6
Biue and grey metal with post	31	6	535	0

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	Thickness Ft.	in.	Depth Ft.	in.
Coal	–	8	535	8
Seggar	11	10	547	6
Post and blue shale	10	6	558	0
Coal. **Townley**	**2**	**2**	**560**	**2**
Seggar	6	0	566	2
Grey shale	18	0	584	2
Seggar	14	7	598	9
Coal	–	11	599	8
Band	–	2½	599	10½
Coal	–	3½	600	2
Seggar	4	6	604	8
Grey and black parroty shale with sandstone post	14	4	619	0
Coal. **Tilley**	**1**	**3**	**620**	**3**
Fireclay	4	0	624	3
Grey sandstone	24	0	648	3
Coal. **Top Busty**	**1**	**8**	**649**	**11**
Seggar and blue shale	5	6	655	5
Coal. **Bottom Busty**	**2**	**3**	**657**	**8**
Seggar	6	0	663	8
Hard grey shale	39	11	703	7
Coal	1	1	704	8
Seggar	3	0	707	8
Grey shale and sandstone ribs	21	5	729	1
Black parroty shale	1	6	730	7
Hard grey shale and white post	18	10	749	5
Black parroty shale	–	11	750	4
Coal	–	3½	750	7½
Band	–	2½	750	10
Coal	1	2	752	0
Seggar merging downward into blue shale	18	10	770	10
Coal. **Brockwell**	**2**	**6**	**773**	**4**
Seggar	–	5	773	9
Hard grey shale and post panel	7	10	781	7
Coal	–	8	782	3
Seggar	2	6	784	9
Grey shale and sandstone post	28	3	813	0
By borehole in East Pit				
Sandstone post and grey metal	6	10	819	10
Coal. **Victoria**	–	**5½**	**820**	**3½**
Seggar	–	6½	820	10
Ironstone rib	–	11	821	9
Grey shale and leafy sandstone	31	1	852	10
Into blue shale	1	0	853	10

The strata dip very gently eastwards, the inclination being only 1 in 36; apart from a small 2½-ft. fault above the Maudlin Coal, they are undisturbed throughout. Sandstones predominate between the Main and Maudlin seams, but for the rest, shales and fireclays generally separate the coals.

The fossils are confined to plant remains, with a few bands of *Lingula* and estuarine lamellibranchs: no true marine band was met with at any point. The plant remains have been determined by Mr. Burnett and the remainder by Dr. G. W. Lee. Of the plants, 93 specimens were collected, mostly of Westphalian type: the most prolific horizon occurred a short distance below the Hutton

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Seam, where Mariopterids prevailed; many were exceptionally well preserved, as also were the Calamites at this and other levels.

In the 'Summary of Progress' for 1921 (p. 129) Dr. Kidston, in commenting on a list of plants from the North-Eastern Coalfield, remarks that the great bulk of them are of Westphalian type. He notes, however, the presence of forms common to both Westphalian and Lanarkian strata at the Brockwell Coal and their relative scarcity at that level, suggesting a Lanarkian age for this horizon. In the Annfield Plain sinkings only two plants have been found close to the Brockwell. Although neither appears in Dr. Kidston's list from that seam they are in agreement with it in that they are common to both Westphalian and Lanarkian strata.

PLANTÆ

Ferns and Fern-like Plants

	Depth in Feet
Sphenopteris stipulata (*Gutbier*)	84
,, dilatata *L. & H.*	84
Cf. ,, corifolia *Kidston*	210
,, sp.	372
,, obtusiloba? *Brongt.*	396
Diplotmema furcatum (*Brongt.*)	396
Mariopteris *cf.* daviesi *Kidston*	396
,, daviesi *Kidston*	396
,, nervosa (*Brongt.*), *var.* oblongata *Brongt.*	396
,, hirta (*Stur*)	396
Alethopteris lonchitica (*Schl.*)	84
,, decurrens (*Artis*)	84
Neuropteris gigantea *Sternb.*	84, 210, 420
,, obliqua (*Brongt.*)	210, 396
,, ingens *L. & H.*	252
,, heterophylla *Brongt.*	396, 420, 714
,, flexuosa *Sternb.*	396
,, *cf.* obliqua *Brongt.*	420

Equisetales

	Depth in Feet
Calamites suckowi *Brongt.*	360, 386, 612
,, sp.	360, 612, 618, 714
,, ramosus *Artis*	396
,, cisti *Brongt.*	420
,, undulatus *Sternb.*	558, 618

Sphenophyllales

Sphenophyllum cuneifolium (*Sternb.*), *var.* saxifragæfolium (*Sternb.*)	396

Lycopodiales

Lepidodendron obovatum *Sternb.*	534, 540
Lepidostrobus geinitzi *Schimper*	372
,, ornatus *Brongt.*	726
Lepidophyllum lanceolatum *L. & H.*	762
Sigillaria elongata ? *Brongt.*	528
Stigmaria ficoides (*Sternb.*)	354, 624

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CORDAITALES

	Depth in Feet
Cordaites principalis (*Germar*)	744
Sternbergia approximata *Brongt.*	396

SEEDS

Cardiocarpus sp.	612

ANIMALIA

INVERTEBRATA

? Naiadites quadrata (*J. de C. Sow.*) [periostracum]	210
Lingula mytiloides *J. Sow.*	582
Carbonicola *cf.* aquilina (*J. de C. Sow.*)	618
,, *cf.* acuta (*J. Sow.*)	750
Anthracomya sp. [periostracum of small form]	762

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APPENDIX V

The Thickness and Distribution of certain members of the Permian System in Yorkshire and Nottinghamshire.

By G. V. Wilson, B.Sc.

Text-figures 19, 20.

The large number of shaft-sinkings and borings, which have been put down through the newer rocks of Yorkshire and Nottinghamshire in search of coal, have added greatly to our knowledge of the thickness and distribution of the Permian deposits. In the following brief description an attempt is made to summarise and correlate the results obtained.

In the north of the area the basal beds of the Permian consist of sporadically distributed patches of fine-grained, generally yellow, sands, the 'Basal Sands.'[1]

In the south, a bed of breccia up to 6 ft. in thickness has been found at the base of the Permian in nearly all the sinkings and borings between Shireoaks and Sutton on the north and Nottingham on the south.

The thickness of the basal deposits is insignificant when compared with that of the overlying marine sediments of the Marl Slates and the Lower Magnesian Limestone, and the isopachytes shown on the map (Fig. 19) are for the thickness of all the measures between the Carboniferous rocks and the top of the Lower Magnesian Limestone. An examination of this map shows a more or less steady thickening of the beds eastwards in the northern part of the area, and northwards in the southern part. It can also be surmised that the margin of the Permian sea lay only a few miles west of the present outcrop of the Magnesian Limestone, and that it turned sharply to the east in the neighbourhood of Nottingham.

The curving of the lines in the neighbourhood of Doncaster is of great interest. It will be noticed that the axes of the curves have a north-easterly trend, and also that they are parallel to the direction of the Don faults. This fact clearly suggests that these faults were moving during the period of deposition of the limestone, and, as will be pointed out later, the movement probably continued till after the deposition of the Upper Magnesian Limestone. A further proof of such movement is afforded by the swerving of the contour lines of the pre-Permian land surface from their normal course as they cross the line of the Don faults. There are, however, few signs of movement in the overlying Trias.

It will be noticed that a wedge of materials extends westwards towards Checkerhouse. In this area the Marl Slates are thicker than is generally the case so far west, and as no signs of a depression of

[1] Versey, H. C., 'The Beds underlying the Magnesian Limestone in Yorkshire,' *Proc. Yorks. Geol. Soc.*, vol. xx, 1925, p. 200.

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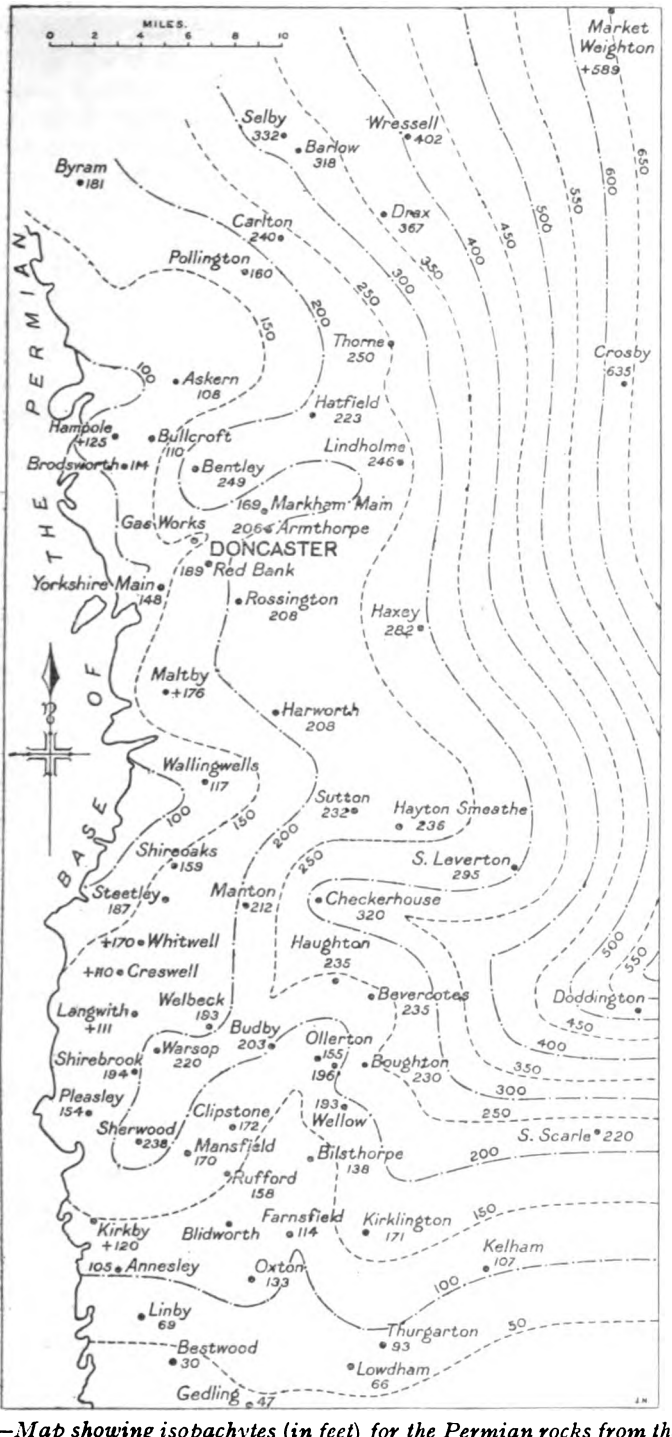

FIG. 19.—*Map showing isopachytes (in feet) for the Permian rocks from their base to the top of the Lower Magnesian Limestone in Yorkshire and Nottinghamshire.*

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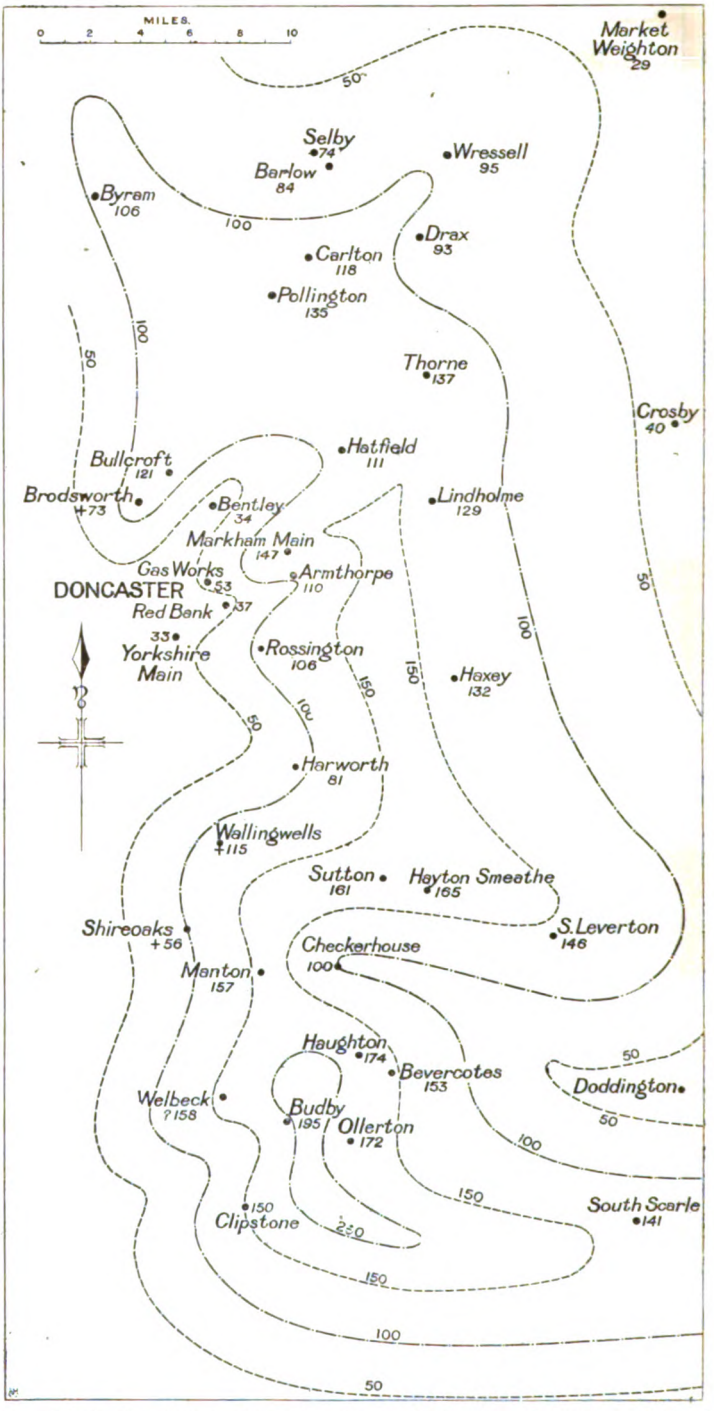

FIG. 20.—*Map showing isopachytes (in feet) for the thickness of the Middle Permian Marls in Yorkshire and Nottinghamshire.*

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the pre-Permian land surface have been noted, it follows that a ridge must occur at the top of the normally thick Lower Magnesian Limestone. The expansion of the Marl Slates is due to the incoming of sandy, shaly materials, which are lithologically almost indistinguishable from Coal Measures sediments; they are interbedded with bands of limestone of the normal type and may, perhaps, be regarded as being contemporaneous with the lower part of the limestone rather than definitely older beds.

The Lower Magnesian Limestone is overlaid by the Middle Marls, and as will be seen from the map (Fig. 20), these beds thin out in all directions in the area in question. They may be regarded as littoral deposits, and it will be noticed that in some parts of the area the marls are thick where the underlying limestone is thin, and in others they are thin where the limestone is thick. This is particularly noticeable in the Doncaster area, where the curving of the isopachytes is in an opposite sense to those for the Lower Magnesian Limestone. It would appear, therefore, that the marls are filling up hollows on the upper surface of the limestone. As these hollows have the same trend as the Don faults it seems probable that they owe their origin to movements of these faults which accompanied the slight upward tilt of the land previous to the deposition of the marls.

Further to the south, to the east of Checkerhouse, it will be noticed that the marls are thin over the slightly elevated area of the upper surface of the Lower Magnesian Limestone, which is presumed to be due to the increased thickness of sandy sediment in that part.

Since the Middle Marls are generally red in colour, and often contain sandstones with desert-rounded grains, it is hardly likely that they have come from the same source as the sediments of the Marl Slates. They are, perhaps, best regarded as being derived from a desert area lying to the west and south, and as having been brought by stream and wind action, and deposited in shallow lagoons situated on a coastal plain which bordered the Upper Magnesian Limestone sea.

There are no signs of an unconformity either at the base or the top of the Middle Marls, and in those districts where they are absent the lower limestone passes up into upper limestone without any break, except such as might well be assigned to local streams or wave action in a shallow sea. It is obvious, therefore, that the Middle Marls are contemporaneous with the basal portion of the Upper Magnesian Limestone of other districts, and their restriction to South Yorkshire and Nottinghamshire may be associated with local earth movements which accompanied the intrusion of the igneous rocks encountered in the Coal Measures at Kirklington, Kelham and Owthorpe borings.

The isopachytes for the Upper Magnesian Limestone show that the filling up of the hollows caused by faulting along the line of the Don faults was still in progress, but over the rest of the area they

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indicate that a more or less general thickening of the materials is taking place in a north-east direction from a line running from a point about 8 miles south of South Scarle to between Budby and Clipstone.

In those parts of South Nottinghamshire where the Upper Magnesian Limestone is absent it is practically impossible to fix a dividing line between the Middle and Upper Marls; and since the Upper Marls pass up into the Trias it is very difficult to assign a definite thickness to them in any part of the area. When the beds overlying the Upper Magnesian Limestone consist mainly of marls with beds of gypsum, anhydrite or rock salt it is better to include them with the Permian, but if they contain a good deal of red sandstone of Bunter type they should be considered as Trias.

In general, however, it can be stated that there is a more or less steady thickening of the Upper Marls as they are traced in a north-easterly direction; for instance they are less than 20 ft. thick near Budby and Ollerton; 46 ft. at Sutton; 82 ft. at Haxey; 102 ft. at Crosby and 212 ft. at Market Weighton.

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APPENDIX VI

On a Borehole in Lower Oolitic Rocks at Wincanton, Somerset

By Wilfrid Edwards, B.A., and J. Pringle

Text-figures 21, 22.

The following is a description of the strata encountered in a boring to a depth of 845 ft. at Wincanton, on the premises of the West Surrey Central Dairy Co. We have to thank Messrs. Manfield Ltd. and the West Surrey Central Dairy Co. for enabling us to examine the cores, and Mr. A. W. Moore for valuable help given us in this examination.

The strata passed through are tabulated below.

Borehole[1] about 350 yds. S.E. of the church, Wincanton. About 260 ft. above O.D.

		Thickness Ft.	Thickness in.	Depth Ft.	Depth in.
	Surface soil and loose limestone ..	1	6	1	6
? Oxford Clay and Kellaways Beds	Mottled brownish yellow clay ..	10	6	12	0
	Blue clay, passing down into blue-grey marl	6	6	18	6
Cornbrash ..	Fossiliferous rather sandy marl ..	1	6	20	0
	Grey fossiliferous limestone with an 8 in. bed of marly sandstone at 24 ft. 8 in.	9	0	29	0
	Dark grey sandy limestone, with angular pebbles of grey limestone	6	0	35	0
	Grey and blue earthy and shelly limestones	12	0	47	0
Forest Marble ..	Grey marl, with 2 thin limestone partings, and thin lignite bands below 65 ft.	29	6	76	6
	Hard blue limestone with angular fragments of grey marl	5	0	81	6
	Sandy limestone with marl partings in lowest foot	4	0	85	6
	Alternating grey papery marl and argillaceous limestone, in thin beds	6	6	92	0
	Grey marl and clay with thin beds of blue shelly limestone	46	9	138	9
	Blue shelly limestone with grey marl partings	6	0	144	9
	Blue limestone with fragments of grey marl. *Rhynchonella boueti* Dav.	5	3	150	0
Upper Fuller's Earth Clay	Grey marl with thin beds of argillaceous and shelly limestone; papery shales in lowest 2 ft. ..	36	5	186	5
	Fine-grained grey sandstone ..	4	6	190	11
	Grey marl	6	11	197	10
	Shaly argillaceous limestone ..	10	0	207	10
	Grey marl with beds of grey argillaceous limestone in lowest 15 ft.	47	2	255	0
	Grey clay	135	0	390	0

[1] Dug well to 18 ft. 6 in.

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		Thickness Ft.	in.	Depth Ft.	in.
Fuller's Earth Rock	Fossiliferous earthy limestone, with beds of dark clay in top part. Becomes sandy in lowest 4 ft, passing down into :—	35	0	425	0
Lower Fuller's Earth Clay	Dark greenish-grey sandy marl with abundant *Ostrea acuminata* J. Sow.				
	1 ft. of grey limestone at 431 ft. ..	6	6	431	6
	Dark green sandy limestone with *O. acuminata* in top foot. Marly at base	6	0	437	6
	Thin alternations of grey earthy limestone and marly clay	27	9	465	3
	Grey clay with several thin beds of marly limestone: *Astarte elegans* J. Sow.	79	9	545	0
Inferior Oolite ..	Massive oolitic limestone, the topmost foot cemented with marcasite. *Acanthothyris obornensis* S. Buckman & Walker	15	6	560	6
	Earthy limestone with thin marly partings in upper 20 ft., and nodular below 604 ft. *Acanthothyris* cf. *obornensis*, *A.* cf. *spinosa* (Linn.) and *Terebratula spp.* [T. globata *Auctt.* & T. sphaeroidalis *Auctt.*]	94	6	655	0
	Fine-grained grey limestone with irregular partings of dark silty clay and marl, which become numerous and thicker below 715 ft. *Ludwigella sp.* at 735 ft. and *Rhynchonella ringens* (von Buch) at 745 ft.	100	0	755	0
	Dull yellow-brown crystalline limestone with angular fragments of grey limestone	2	0	757	0
	Lumpy grey-brown earthy limestone, slickensided. Occasional silty clay partings	28	0	785	0
Bridport Sands	Fine-grained grey micaceous sand, weathering greenish-brown, with numerous beds of grey sandy limestone, 1 to 2 ft. thick. The sand becomes silty and laminated and darker in colour below 820 ft.	60	0	845	0

The strata have no measurable dip down to the depth of 550 ft., but at 600 ft. an inclination of 5° was observed, and lower down the beds are seen to be dipping at gradually increasing angles, 30° at 750 ft., 45° at 780 ft., and 50° at 845 ft. being observed. The high dip and the presence of slickensides in the Inferior Oolite limestones suggest the proximity of a fault. In the diagram on p. 186 the thicknesses of the strata in the lower part of the borehole are shown corrected for dip. The section is similar to that proved at Stowell, 4 miles to the S.S.W.[1], but in addition the whole of the

[1] 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), p. 83; for 1909, p. 68.

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Upper Fuller's Earth Clay, the Forest Marble and the Cornbrash are present. Some portion of the clay above the Cornbrash probably represents the Kellaways Beds, and the lower part of the Oxford Clay. The following fossils were found in the Cornbrash:—*Terebratula intermedia* J. Sow., *Gervillia ?*, *Modiola sp.*, *Pecten* (*Syncyclonema*) *demissus* Phill., *Pinna sp.*, *Placunopsis sp.*, *Pseudomonotis echinatus* (J. Sow.), *Pteria* (*Oxytoma*) *costata* (J. Sow.), *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.).

The lower beds of the Forest Marble are present in almost similar facies to that of the corresponding beds at Westbury[1] and the lower part of the clay is equivalent to the Bradford Clay, the characteristic brachiopod *Rhynchonella boueti* Dav. being abundant in a fossiliferous band at the base. There were also found in the Forest Marble *Ostrea sp.*, *Pecten* (*Camptonectes*) *lens* (J.Sow.), *Pecten sp.* and *Pleuromya sp.*

The Upper Fuller's Earth Clay consists mainly of grey marl with layers of argillaceous limestone, and from the beds the following fossils were obtained:—*Rhynchonella smithi* Walker, *Lima sp.*, *Modiola sp.*, *Modiola gibbosa* J. Sow., *Ostrea sp.*, and *Pleuromya ?*. Impressions of small ammonites were found in abundance in the lower part of the clay, but none could be identified. In the Fuller's Earth Rock were found specimens of *Rhynchonella smithi* Walker, *Rhynchonella sp.* ('*concinna*' group), *Terebratula globata* J. de C. Sow., *Cyprina sp.*, *Modiola gibbosa* J. Sow., *Ostrea sowerbyi* Morris & Lycett and *Trigonia* cf. *costata* J. Sow. The clay band crowded with *Ostrea acuminata* J. Sow. (*sensu stricto*) is present below the Fuller's Earth Rock. The Lower Fuller's Earth Clay is thinner here than at Stowell, and bands of limestone are more abundant in it. Near the base *Astarte elegans* J. Sow. is a characteristic shell, as at Stowell. Besides the two fossils mentioned, there were found *Lima sp.*, *Ostrea sp.*, *Pecten* (*Camptonectes*) *sp.*, *Pholadomya sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.) and *Siemiradzkia* aff. *aurigera* (Oppel).

Although the Inferior Oolite deposits are closely similar to those proved at Stowell, the beds between the top of the formation and the horizon of Rhynchonella ringens are considerably thicker, and since the Concava Zone is represented[2] it is probable that the sequence of zones is more complete here than at Stowell, where the Niortensis, Blagdeni and Concava Zones appear to be missing. Below the Ringens Bed the rocks are disturbed and probably faulted, and cannot be correlated. It is clear, however, that the Bridport Sands were entered at a depth of 785 ft. They were only penetrated to a depth of 60 ft. or a thickness of 46½ ft., allowing for dip. In the Inferior Oolite were found specimens of:—

Acanthothyris obornensis *S. Buckman & Walker*, 546 ft.
,, *cf.* obornensis *S. Buckman & Walker*, 566 ft. to 597 ft.

[1] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 147.
[2] Indicated by the presence of species of *Ludwigella*.

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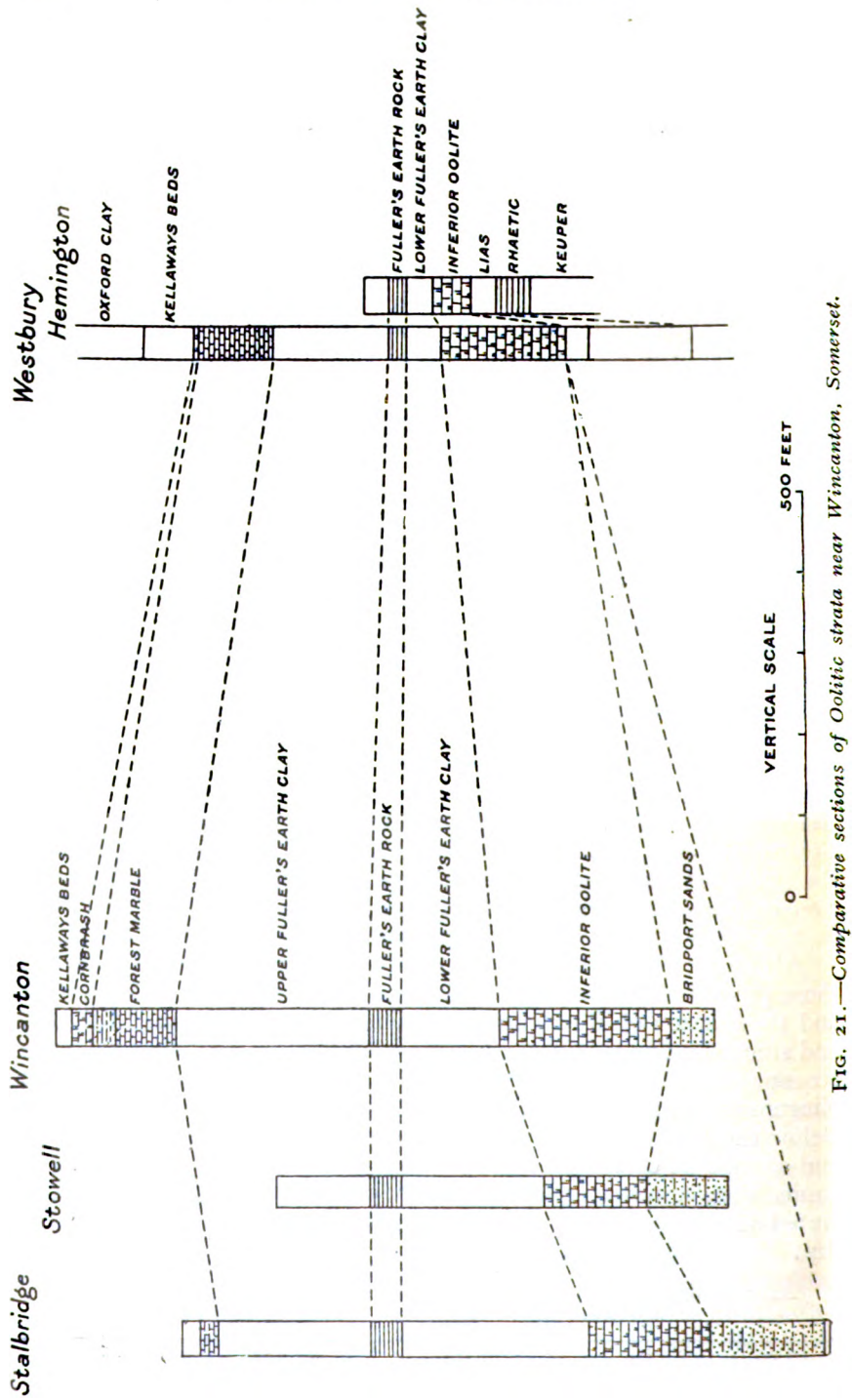

FIG. 21.—*Comparative sections of Oolitic strata near Wincanton, Somerset.*

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Acanthothyris *cf.* spinosa (*Linn.*), 592 ft.
,, sp., 544 ft., 564 to 575 ft., 609 ft., 682 ft.
Aulacothyris sp., 594 ft.
Rhynchonella ringens (*von Buch*), 745 ft.
Terebratula sp., 575 ft.
,, sphaeroidalis *Auctt.*, 576 ft.
,, sp. [*T. globata* Auctt.], 594 ft.
,, sp. [*T. sphaeroidalis* Auctt.], 594 ft.
,, *cf.* perovalis *J. de C. Sow.*, 782 ft.
,, sp. [=*T. decipiens* Dav., pars=elongate form of *T. sphaeroidalis* Auctt[1]], 740 ft.
Isocardia ?
Lima (Plagiostoma) sp. [small], 597 ft.
Modiola sowerbyana *d'Orb.*, 717 ft.
Pteria (Oxytoma) inaequivalvis (*J. Sow.*), 760 ft.
Trigonia *cf.* costata *J. Sow.*
,, sp. [like *T. navis*], 782 ft.
Ludwigella sp., 735 ft.
Belemnites sp.

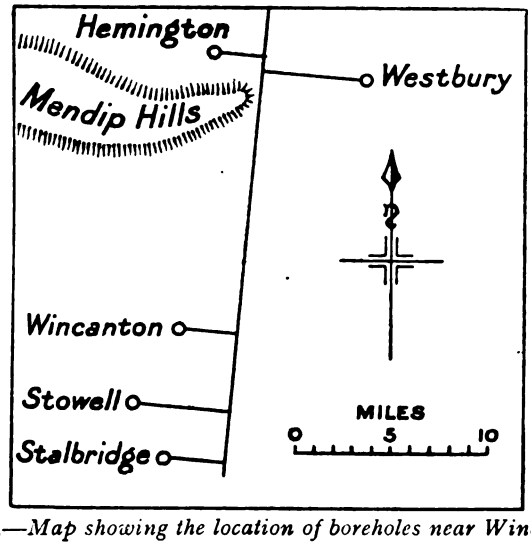

FIG. 22.—*Map showing the location of boreholes near Wincanton.*

The fossils found in the beds between the depths of 800 and 845 ft. include *Ostrea* (*Alectryonia*) *sp.*, *Pecten* (*Syncyclonema*) *sp.*, *Pteria* (*Oxytoma*) *inaequivalvis* (J. Sow.), *Trigonia sp.*, *Belemnites sp.*, *Cotteswoldia ?*, *Lioceras sp.* and *Pleydellia ?*. Dr. L. F. Spath, who has examined the ammonites, states that the deposits fall within the Aalensis-Opalinus Zones, so that the sands clearly correspond to the Bridport Sands of the Bridport district.

This borehole is one of a number which have been made in the Lower Oolites of the East Somerset neighbourhood[2]. The sections

[1] *See* Stowell boring, 'Summary of Progress' for 1909 (*Mem. Geol. Surv.*), 1910, p. 69.

[2] Purse Caundle, *see* Stalbridge bore, 'Wells and Springs of Dorset' (*Mem. Geol. Surv.*), 1926, p. 67.
Stowell, *see* 'Summary of Progress' for 1908 (*Mem. Geol. Surv.*), p. 83; for 1909, p. 68.
Westbury, *see* 'Summary of Progress' for 1921, p. 146.
Hemington, *see* 'Summary of Progress' for 1913, p. 98.

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from these boreholes have been plotted in the diagram (Fig. 21) above, the distances apart of the sections being proportioned to their distances apart on the ground when projected on to the line marked on the sketch map (Fig. 22), running roughly at right angles to the axis of the Mendip Hills. The considerable southward thickening of the Lower Oolite strata away from the Mendip Hills is indicated in the diagram, the increase being due chiefly to the clay formations[1].

[1] Of the borehole at Purse Caundle (Stalbridge) no detailed geological information is available, but the interpretation of the section made by Messrs. Duke and Ockenden is probably nearly right.

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APPENDIX VII

On a New Species of *Phyllobrissus* from a deep boring at Virginia Water, Surrey

By Professor H. L. Hawkins, D.Sc.

Phyllobrissus artesianus sp. nov.

Text-figure 23.

One complete specimen (the holotype) and fragments of three others (of about the same size) occurred in a small block of ferruginous glauconitic sandstone from a depth of about 1,430 ft. in the boring for water recently made at the Holloway Sanatorium, Virginia Water (Surrey).

In the following description the proportions are taken from the holotype, but most of the details have been detected most clearly on the fragments. No such details are included unless some indication of them has been found on the holotype. The specimens are in the collection of the Geological Survey and Museum, numbered 37948 (holotype), 37949, 37950, and 37951.

Measurements:—

Length	17·5 mm.	(1).
Breadth	14·7 mm.	(0·84).
Height	9·0 mm.	(0·51).

Test small, tumid, fairly thick.

Ambital outline more or less elliptical, subangular; anterior margin transverse, sides diverging with slight curvature to the widest point at ambulacra I and V: thence converging sharply to a slight indentation below the posterior sulcus.

Adapical surface tumid, rising steadily from the front to the highest point behind the apical system and just above the periproct (see Fig. 23, 4).

Adoral surface tumid, especially interradially.

Apical system very slightly anterior to the mid-point, not at the summit of the test; details obscure.

Peristome excentric anteriorly, deeply invaginate, transversely elliptical, surrounded by a well-developed floscelle.

Periproct high up on the posterior face, at the top of a deep sulcus that reaches and notches the ambitus. This sulcus has sub-parallel sides; and, although it is clearly defined, its margins are not sharp.

Ambulacra narrow, flush and feebly petaloid adapically, expanding into deep and striking phyllodes near the peristome. There seem to be remarkably few pores in the phyllodes, but they are manifestly constructed on the normal triadic plan (see Fig. 23, 5).

Interambulacra covered with very small scrobiculate, perforate tubercles adapically; the tubercles become larger and more sparse

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adorally. In area 5 there is a narrow median belt (between the posterior ambital notch and the peristome) where no major tubercles occur; but there are numerous minute tubercles and granules on it. The peristomial bourrelets are extremely prominent and by their

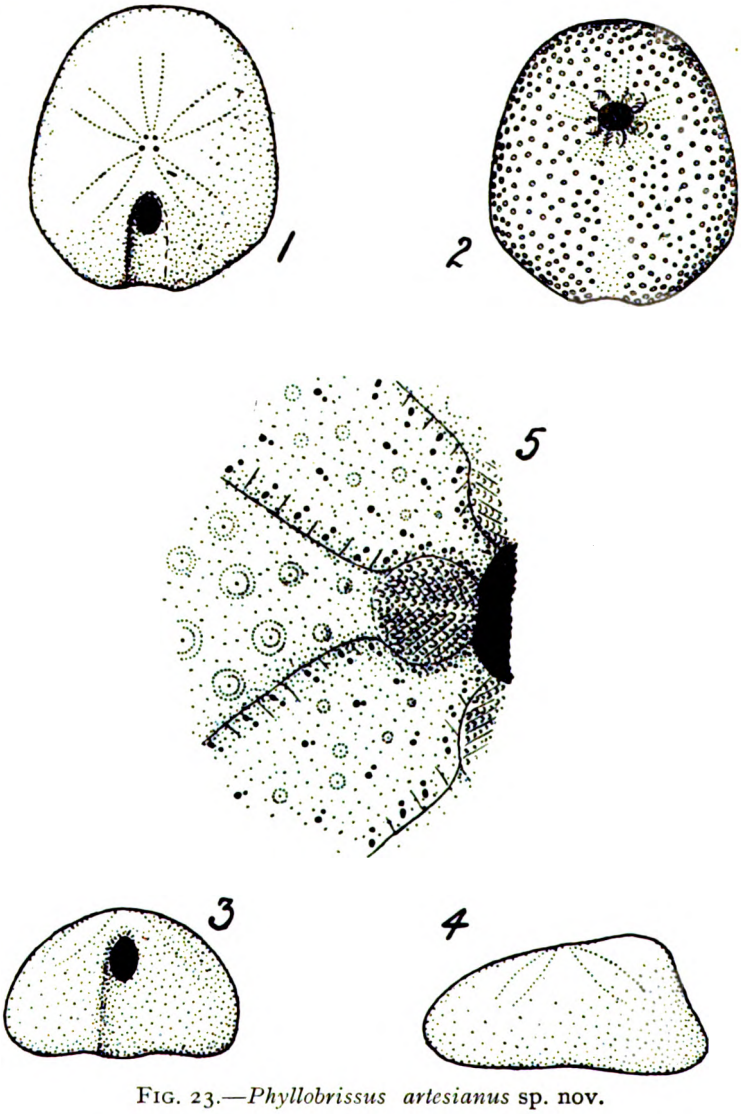

FIG. 23.—*Phyllobrissus artesianus* sp. nov.

1. Adapical view
2. Adoral view
3. Posterior view
4. Lateral view

} of Holotype [37948]

5. Part of the floscelle of another specimen [37949]

(The figures are enlarged; for actual size see text.)

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expansion reduce the phyllodes to narrow grooves at the peristome-margin; they are covered with very even and numerous granules arranged in divergent lines (see Fig. 23, 5).

Comparisons.—This is a thoroughly typical *Phyllobrissus*.

When compared with the only other species of the genus known from Britain, *P. fittoni* (Wright, sub *Clypeopygus*), *P. artesianus* is seen to be smaller and proportionately much higher. In *P. fittoni* the apical system is at the highest point of the flattish test, and the posterior surface is not markedly steeper than the sides, while the sulcus is shallow. In the peristomial region the resemblance between the two species is rather closer, but the pore-pairs of the phyllodes are more numerous and close-set in *P. fittoni* than in *P. artesianus*.

A much closer comparison is possible between *P. artesianus* and *P. cerceleti* (d'Orbigny, sub *Clypeopygus*). Again *P. artesianus* proves much smaller; but in outline, height and other proportions the two forms are strikingly alike. In the peristomial region, however, a difference is found; in *P. cerceleti* the bourrelets of the floscelle are relatively feeble, while in *P. artesianus* they are unusually distinct.

There is no other species of *Phyllobrissus* known to me with which comparison would be profitable.

Horizon indicated.—Both of the species with which *P. artesianus* is comparable are restricted to the Aptian. *P. fittoni* occurs in the Shanklin Greensand together with *Exogyra sinuata* and *Rhynchonella parvirostris*; and *P. cerceleti* seems to be known only from the Aptien of Grandpré (Ardennes). Since *P. artesianus* shows characters approximately intermediate between those of the two species known previously (the points in which it differs from one are those in which it resembles the other) it might be assumed in the absence of contrary evidence that some of the ferruginous green sandstone found at the depth of 1,430 ft. at Virginia Water is of Aptian age.

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APPENDIX VIII

New Goniatites from the Millstone Grit of Lancashire

By W. B. Wright

Plate XII. Text-figure 24.

The tracing into Lancashire of the goniatite-sequence established by Mr. W. S. Bisat[1] in Yorkshire has revealed some interesting variations from the type district. Only the upper portions of the Millstone Grit Series are available for study over a wide area, exposure of the lower portions being local. In the upper beds

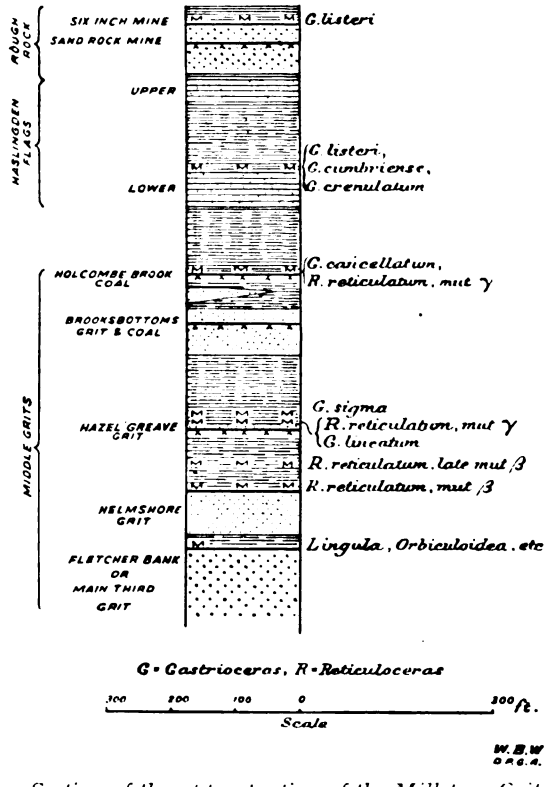

Fig. 24.—*Section of the upper portion of the Millstone Grit Series in the district north of Bury and Bolton.*

the main change is a marked thickening of the succession to the south-west[2], accompanied by more frequently repeated and more protracted marine conditions. This brings in some new forms and

[1] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, vol. xx, Part I, 1924.

[2] Tonks, L. H., and W. B. Wright, 'The South-Westerly Thickening of the Millstone Grit in Lancashire,' in 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, Appendix ii, p. 150.

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fills up gaps in the evolution of others. The purpose of the present paper is to describe a new species of *Gastrioceras* earlier than any hitherto known, a second species of considerable zonal significance doubtfully referred to *Gastrioceras*, and a further evolutionary development of *Reticuloceras reticulatum* (Phill.), intermediate between Bisat's[1] mutations β and γ.

The accompanying section (Fig. 24) gives the stratigraphical succession in the area from which the fossils are obtained and the position of the marine bands containing them. It should be noted that although *Gast. lineatum* will now be the earliest described species of *Gastrioceras*, there are indications that forms with affinity to *Gast. cancellatum* Bisat occur as low as the Early-γ-Bed; but it has not yet been possible on account of their rarity to get enough material to ascertain if they are, as seems likely, distinct from *G. cancellatum*.

Mr. Bisat has been kind enough to read the accompanying descriptions and compare them with the type specimens. He has made a number of valuable suggestions, most of which have been adopted.

Development of the Marine Bands.—An account of the marine bands in the Millstone Grit of South Lancashire will be given in the Geological Survey Memoir on Sheet 76 now in preparation. It is only necessary to note here that the Early-γ-Bed is known only from South Lancashire, being replaced to the north and east by sandy strata. The γ-Bed is thicker and contains a greater variety of forms in this district than to the north-east, and it fails altogether in the Cliviger district between Burnley and Todmorden. The *Sigma*-Bed has a wider distribution and occurs in Cliviger, but up to the present has only been traced in South Lancashire. The *Sigma*- and γ-Beds come very close together in places, and forms resembling *Gastrioceras ? sigma* occur in the γ-Bed, but mut. γ has never yet been seen in the *Sigma*-Bed.

Descriptive Terms.—Some of the descriptive terms employed below, being new, require explanation. Transverse striae are briefly referred to as 'radials,' spiral striae as 'spirals.'

In the mutations of *R. reticulatum* there is a tendency to develop two spiral grooves along the lingua near the points of inflexion of the radials, where the latter pass from the side to the lingua and from the lingua to the sinus. The innermost of these grooves coincides approximately with the inner row of points of inflexion, but the outermost is appreciably nearer the umbilicus than the outer row of points of inflexion. The area between these 'inflexional

[1] Mr. Bisat states definitely, *op. cit.*, p. 119 (78 of reprint), that *G. bilingue* of Salter is the equivalent either of mut. β or early mut. β or both. Again on p. 51 (p. 12 of reprint) he suggests the use of *R. bilingue* for mut. β. Salter's name would, in ordinary circumstances, have priority. As, however, there is no type specimen of *G. bilingue*, and as the description is inadequate, the figure unsatisfactory, and the horizon unknown except in the broadest sense, it is considered advisable to follow Mr. Bisat's nomenclature.

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grooves' is a ridge on the exterior of the shell, whose edges become acutely marked in the later mutations. It may be conveniently referred to as the 'wheel.' A thickening of the test, accompanied probably by a parting of the inner and outer layers of the shell along the line of the wheel, tends to fill in the corresponding internal groove or even, as in mut. γ, to convert it into a ridge, which leaves its mark on internal casts as an equally conspicuous spiral groove.

Reticuloceras reticulatum, early mut. γ, mut. nov.

Plate XII, figs. 1, 2, 6.

This form has obviously evolved from *R. reticulatum*, mut. β Bisat, into which it passes by a series of intermediate forms and with which it intermingles in the two marine bands above the Helmshore Grit in the districts north of Bolton and Bury, becoming, in the uppermost of these marine bands, the dominant form. It is clearly transitional to Bisat's mut. γ, and the four forms early mut. β, mut. β, early mut. γ and mut. γ represent without question a direct line of descent.

Description.—Radial striae on the exterior of the test in adult non-crenulate or, in adolescence, very slightly sub-crenulate on the sides, but always, when well preserved, seen to be crenulate where they cross the lingua. Spiral striae on lingua only. Inflexional grooves and wheel well marked from a diameter of 10 or 12 mm. onwards, sometimes even from 5 mm. Lingua and sinus on the average more pronounced and of earlier development than in mut. β, less pronounced and of later development than in mut. γ. Expansion of the wheel in adolescence also intermediate between these two forms. Diameter at maturity normally 20–25 mm., but sometimes approaching 40 mm.

Horizon.—The marine bands above the Helmshore Grit in the districts north of Bolton and Bury. The upper of the two marine bands has up to the present only been found in this region, being replaced to the north and east by sandy strata, the Hazel Greave Grits. In it early mut. γ is the dominant form, but an admixture of mut. β is still apparent. In the lower marine band, which lies a few feet above the coal on top of the Helmshore Grit, it is comparatively rare. Transitional forms from mut. β to early mut. γ occur in both beds, and there is clearly an evolutionary progression from one to the other.

Localities.—(1) Cheesden Brook near main Edenfield-Rochdale Road; shale cliff 240 yds. downstream from Cheesden Lumb Mill. The two marine bands are one at the bottom and the other at the top of the cliff. 6 in. map Lancs. 80 S.W. 1 in. map 76. [S.H. 283–292 and 1777–1787 (lower band) and S.H. 1788–1826 (upper band)][1]. (2) Hodge Clough; 1500 yds. N.N.W. of Stubbins Station, Ramsbottom, section by fork in stream (lower band),

[1] Numbers in brackets are those of the Geological Survey Collections.

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and 150 yds. higher upstream (upper band). 6 in. map Lancs. 79 N.E. 1 in. map 76. [S.H. 2068–2108 (lower band) and S.H. 2109–2164]. (3) Section in left bank of stream, 300 yds. S.E. of Witton's Farm, Hall Wood, Longworth Valley, W.N.W. of Egerton. 6 in. map Lancs. 78 S.E. 1 in. map 76. [S.H. 305–326]. Type locality. (4) Stream 300 yds. N.E. of Higher Hempshaws, 2 miles W. of Belmont. 6 in. map Lancs. 78 S.W. 1 in. map 75. [S.H. 3036–3062].

Type Material.—Holotype, 37930; metatypes, 37928 and 37921, from locality (3). Paratypes, 37929 and 37930 from locality (1), and 37931 and 37922 from locality (4). All in Survey Collections.

Remarks.—The following characters serve to distinguish this form from mut. β:—

(1) The radials on the lateral area of the test show less tendency to crenulation at all stages of growth; up to 20 mm. diam. they are slightly but distinctly sub-crenulate, beyond this they are consistently non-crenulate as in mut. γ.

(2) The wheel is narrow and regular and traceable back to a small diameter (10 mm. observed in two cases [37929 and 37930], and 5 mm. in one [S.H. 1814]).

(3) The lingua and sinus are more pronounced and of earlier development.

(4) In β, especially during adolescence, there are generally two (or sometimes three) spiral striae on the lingua, more pronounced than those adjoining them and also more widely spaced. This character is greatly reduced in early γ.

The following characters separate it from mut. γ:—

(1) The rate of expansion in adolescence and at maturity is greater, the lingua showing marked divergence from the periphery of the preceding whorl.

(2) The radials on the lateral area are sub-crenulate up to about 20 mm.

(3) There are always spiral striae on the lingua and the radials are always crenulate where they cross it.

The test appears to be slightly thickened on the lingua between the inflexional grooves, but not often sufficiently so to make a groove upon the cast, as in mut. γ. There is some slight evidence [e.g. S.H. 283] to indicate that this thickening is hollow and brought about by the separation of two layers of the shell, the outer of which is ornamented on both sides and the inner smooth.

The link with mut. γ is rendered almost complete by the rare occurrence in the γ-Bed of a form in which the radials are distinctly crenulate where they cross the lingua.

The following approximate measurements are cited for comparison with those given by Mr. Bisat for early mut. β, mut. β and mut. γ. It is not claimed that they have diagnostic value.

(1) Forward projection of lingua in mm., 3 at 12 mm. diam., 3–4 at 14. 4 at 18, 4–5 at 20, 5–6 at 24, 7–8 at 28 (?).

(2) Width of lingua in mm. between the points of inflexion, 1·25 at 12 mm. diam., 1·5 at 15, 1·75 at 22, 2 at 27.

(3) Depth of hyponomic sinus in mm., over 10 at 30 mm. diam., only one measurement possible and that a minimum.

(4) Number of striae to mm. on lingua, 3 at 14 mm. diam., 3–5 at 22, 4–5 at 30, very inconstant.

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The following analytical table has been prepared in collaboration with Mr. Bisat:—

(*a*) Lingual ridge on test wide and diffuse, 'inflexional' grooves absent or vague .. .. α and β

(*b*) Lingual ridge on test narrow and wheel-like, 'inflexional' grooves sharply marked:—

(b_1) Lingual groove on internal cast absent or slight, spiral striae on lingua, radials crenulate where they cross the lingua .. .. early γ

(b_2) Lingual groove on internal cast present and generally strong, no spirals, radials non-crenulate throughout .. γ

This table should be applied to specimens 15–20 mm. in diameter or to larger specimens at this diameter. Some specimens of the later forms of β tend in old age to develop the character of early γ.

Gastrioceras lineatum sp. nov.

Plate XII, figs. 3, 4, 8.

It has for some time been known that in South Lancashire at any rate certain forms of the genus *Gastrioceras* Hyatt occur at slightly lower levels in the Millstone Grit Series than the base of Mr. Bisat's zone G. Of these, one has been found to occur sufficiently frequently and to be sufficiently definite in its characters to merit separation as a distinct species. It is proposed to give it the descriptive name *Gastrioceras lineatum*.

Description.—Form unknown but probably sphaerocone or ellipsocone, umbilicus open, about one third of diameter, with steep inner slope and showing the tubercles of the interior whorls. Strongly tuberculate, the tubercles tending to extend on to the lateral area as tubercular ribs. Rate of expansion about that normal to *Gastrioceras*. Ornament in adult consisting of extremely delicate radial striae which are quite uncrenulate even on the tubercles. Spiral striae completely absent. The radials take the form of minute forward facing imbrications on the exterior of the test. Lingua and sinus very slight (stage 2, Bisat). Sutures unknown. Usual diameter at maturity 25–35 mm.

Horizon.—The γ-Bed above the Hazel Greave Grits in the Blackburn and Bury districts, South Lancashire. Where the Hazel Greave Grits die out westwards the γ-Bed occupies a position in the shales between the uppermost β-Beds and the *Sigma*-Bed and lies about 30 ft. above the Helmshore Grit.

Localities.—(1) Stream bank below the Haslingden—Helmshore Road, 850 yds. N.W. of Helmshore Station, Lancashire. 6 in. map Lancs. 71 S.E. 1 in. map 76. [S.H. 3103–3121]. Type locality.

(2) Royshaw Brickworks, 1750 yds. due N. of Blackburn Station, section E. of fault, on N. side of pit, just west of pond. 6 in. map Lancs. 62 S.E. 1 in. map 76. [R.E. 4399–4421].

Type Material.—Holotype, 37923; metatypes 37932, 37933, and 37924, all from locality (1). Paratypes, 37925, 37934, and 37935, from locality (2). All in the Geological Survey Collection.

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Remarks.—This species approaches most nearly to *G. listeri*, from which it may be distinguished, however, by the greater delicacy of its ornament and by the complete absence of crenulation on the tubercles. The ornament in the very young may possibly be coarser, in which case the first distinction may break down as regards immature specimens. Moreover, occasional specimens of *G. listeri* are rather delicately ornamented, so that the character of the peripheral striae cannot be claimed to be absolutely diagnostic. The absence of crenulation on the tubercles seems to be the best distinguishing character. The radials issue from the umbilicus approximately at right angles. In metatype 37933 vague spiral ribbing appears on the periphery but is regarded as exceptional. Paratype No. 37925 has 24 tubercles to the whorl at a diameter of 28 mm. The other specimens do not admit of a count of tubercles being made, and it is not known if the number is constant either in the species or in the individual during development.

Gastrioceras? *sigma* sp. nov.

Plate XII, figs. 5, 7.

At varying distances up to 10 ft. above the γ-Bed on top of the Hazel Greave Grits, and sometimes descending into this bed, there occurs a goniatite which, while poorly preserved and indefinite in its characters, is yet sufficiently distinct and sufficiently constant in its occurrence to merit description. It has been extensively used for correlation purposes by the geologists of the Lancashire unit of the Geological Survey, being referred to by them as 'sigma' mainly for the sake of having some name, but also in reference to the double swing of the transverse striae or radials as they pass from the umbilicus to the periphery, giving an obscure resemblance to the Greek capital letter Σ. This temporary symbol is now adopted as the specific name, but the character it implies is in no sense diagnostic, being found in a number of other goniatites.

Description.—Form ellipsocone [37945–7]. Umbilicus small, steep-sided, one-fifth of diameter or less. Rate of expansion about that normal to *Gastrioceras*. Exterior of test ornamented with radial striae, crossed, especially near the periphery, by indefinite obtuse spirals [37927] which are generally but not always apparent. Mouth form in stage 2 of Bisat, lingua and sinus slight. The young stage up to about 3 mm. is distinctly ribbed transversely [37926–7, 37936–45], and in adolescence the striae arise by branching from these ribs. There is, however, no distinct tuberculation. The sutures are unknown. Usual diameter at maturity 20–30 mm.

Horizon.—The *Sigma*-Bed, from 3 to 10 ft. above the γ-Bed throughout the Rossendale Anticline, and extending further north-east than the latter bed. The species is everywhere present in the bed except in Paul Clough, 1 mile N.E. of Portsmouth Station, where only *Lingula* and fish-remains have been found.

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Localities.—(1) Tower Clough, S.E. branch, 1000 yds. S.E. of Portsmouth Station. 6 in. map Lancs. 73 N.W. 1 in. map 76. [R.E. 4752–9, S.H. 698–707].

(2) Green's Clough, 450 yds. W. of Portsmouth Station. 6 in. map Lancs. 73 N.W. 1 in. map 76. [R.E. 4611–32].

(3) Section by fork in stream, 200 yds. W. of Ragby Bridge, Ramsden Wood, Walsden. 6 in. map Lancs. 73 S.W. 1 in. map 76. [S.H. 166–173].

(4) Section in bank, S. side of reservoir above Vale Mill, Waterfoot, 600 yds. W. 8° S. of Waterfoot Station. 6 in. map Lancs. 72 S.W. 1 in. map 76. [S.H. 1365–93].

(5) Stream section, 200 yds. from road, S.W. of Ryal Fold, Liverpool Corporation Waterworks, 4030 yds. W. of Darwen Parish Church, Lancashire. 6 in. map Lancs. 70 S.E. 1 in. map 75. [R.E. 4456–66, S.H. 2573–2608].

(6) Ironstone Pit, ⅛ mile a little N. of E. from summit of Bull Hill, 1½ miles N. 30°W. from Ramsbottom Station. 6 in. map Lancs. 79 N.E. 1 in. map 76. [S.H. 2190–2205].

(7) Section in stream N.E. of Higher Hempshaws, 2 miles W. of Belmont, Lancashire, 7 ft. 6 in. above the γ-Bed. 6 in. map Lancs. 78 S.W. 1 in. map 75. [S.H. 3085–98]. Type locality.

(8) By roadside, 350 yds. N. of the E. end of Knowsley Embankment, Charnock. 6 in. map Lancs. 78 S.W. 1 in. map 75. [S.H. 3406–3426].

Type Material.—Syntypes:—37936, 37937, 37926, 37927, 37938, 37939, 37940, 37941, 37942, 37943, 37944, 37945, 37946, 37947. All from locality 7.

Remarks.—The radial striae appear to be generally of the nature of two-sided ridges and not imbrications as in *G. lineatum*. They are often accompanied by rippling which is, however, probably not a specific character. Constrictions occur occasionally. A very common character, due in part no doubt to the state of preservation, is the spiral cracking of the test which is apparently guided by the obtuse and not always apparent striation.

G.? sigma is distinguished from *G. lineatum* by the absence of tubercles, by the character of the radial striae which are coarse and ridge-like, and by the common presence of spiral striae or spiral cracks. It is distinguished from *G. cumbriense* Bisat (to some specimens of which it bears a certain resemblance) by the absence of tubercles and by the relative indefiniteness and obtuseness of the spiral striae.

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Goniatites from the Millstone Grit of **Lancashire.**

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DESCRIPTION OF PLATE XII.

Fig. 1.—***Reticuloceras reticulatum***, early mut. γ, mut. nov. Marine band above the Helmshore Grit. Locality 3 (Witton's Farm). x 2. Metatype [37921].

Fig. 2.—***R. reticulatum***, early mut. γ, mut. nov. Marine band above the Helmshore Grit. Locality 4 (Higher Hempshaws). x 2. Paratype [37922].

Fig. 3.—***Gastrioceras lineatum*** sp. nov. The γ-Bed above the Hazel Greave Grit. Locality 2 (Royshaw Brickworks). Nat. size. Paratype [37925].

Fig. 4.—***G. lineatum*** sp. nov. The γ-Bed above the Hazel Greave Grit. Locality 1 (Helmshore). Nat. size. Metatype [37924].

Fig. 5.—***Gastrioceras? sigma*** sp. nov. The *Sigma*-Bed from 3–10 ft. above the γ-Bed. Locality 7 (Higher Hempshaws). x 3. Syntype [37927]. To show spiral ornament.

Fig. 6.—***Reticuloceras reticulatum***, early mut. γ, mut. nov. Marine band above the Helmshore Grit. Locality 3 (Witton's Farm). x 2¼. Holotype [37920].

Fig. 7.—***Gastrioceras? sigma*** sp. nov. The *Sigma*-Bed from 3–10 ft. above the γ-Bed. Locality 7 (Higher Hempshaws). x 3. Syntype [37926].

Fig. 8.—***Gastrioceras lineatum*** sp. nov. The γ-Bed above the Hazel Greave Grit. Locality 1 (Helmshore). x 2. Holotype [37923].

All the specimens figured are external moulds.

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and the

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for the Year 1926

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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1926

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Seventh Annual Report on the work of the Survey and Museum.

1. The staff of the Geological Survey and Museum was brought up to its authorised strength in the course of the year by an appointment to the vacancy in the grade of 'Geologist', to which we referred in our last Report—a palaeobotanist being selected for this post.

We are pleased to report that the establishment and the personnel have continued to prove sufficient for carrying on expeditiously and satisfactorily the prearranged programme for the year which was duly completed. At the same time, they dealt effectively with the many and varied enquiries that from time to time emerge within the recognised ambit of the Survey.

The Mining Industry Act (1926) prescribed certain extensions of the duties of the Geological Survey (*see* Section 12 below), and we learn that in view of these there has been a small addition to the establishment in minor grades of the staff.

2. While dealing with staff matters we desire to allude to the deaths during the year of two of the Survey's former officers, viz.: Dr. Benjamin N. Peach, F.R.S., and Mr. George William Lamplugh, F.R.S. Though Dr. Peach retired in 1905 and Mr. Lamplugh in 1920 they each continued after retirement to give assistance of much value to the Survey whenever their help was sought. By their deaths the Survey of to-day has lost two trusted advisers. Some particulars of the services of these two distinguished ex-officers are given in the 'Report of the Director' (pp. 31–32).

3. The allocations of the Field Units engaged on surveys of the districts described by the programme for the year were as follows:—

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(*g*) North Highlands (primary six-inch survey).
(*h*) Ayrshire (revision of six-inch survey).
(*i*) Lanarkshire and Peeblesshire (revision of six-inch survey).
(*j*) Fife and Kinross (revision of six-inch survey).

As in previous years the Field Units (*c*), (*d*), (*e*), and (*f*) have worked in direct connection with the Branch Offices of the Survey at York, Manchester, Whitehaven, and Newcastle-on-Tyne respectively. Of these four Branch Offices the last-named has continued to work under the Assistant to the Director in Edinburgh, and the others under the Assistant to the Director in London.

Details of the work carried out by each of the Field Units will be found in the ' Summary of Progress '.

4. The field work of the Survey during the year has consisted in the main of a continuance of the primary six-inch survey of two areas in England, and the revision of several coalfield areas in England and Scotland originally surveyed on the six-inch scale more than thirty years ago, but not since systematically re-examined. In addition, the primary survey on the six-inch scale of an area in the North Highlands of Scotland (Sutherlandshire) was resumed, and resulted in the completion of field work in Sheet 108. In many parts of the country borings and sinkings in search of minerals and water, both outside and within the areas under survey, have been visited and all available details have been carefully recorded and filed.

The Petrographical, Palaeontological, Chemical and Drawing Office staffs at headquarters have co-operated closely with the field staff. The various publications have thus embodied the results of collaboration of officers expert in different aspects of the work.

We regard the progress in field work and indoor work alike as highly satisfactory.

5. Much use has again been made of the assistance of geologists outside the Survey who are possessed of special knowledge. In this connection we may mention the completion of memoirs by Mr. Osborne White on the Hastings and Dungeness Sheets, by Professor P. G. H. Boswell on the Woodbridge and Felixstowe area, by Mr. Linsdall Richardson on the Moreton in the Marsh Sheet, and by Dr. G. W. Tyrrell on the Island of Arran. Mr. Osborne White is now engaged on a volume explanatory of the Ramsgate and Dover Sheets, and Professor Boswell on one relating to the Sudbury area. Apart from District and Sheet memoirs the services of Professor O. T. Jones have been utilised in the preparation of a palaeontological monograph on ' Plectambonites and Some Allied Genera ' and the assistance of Miss E. M. Lind Hendriks has been secured for the preparation of a ' Catalogue of Geological Photographs suitable for educational purposes '. Dr. Franklin Sibly has also supervised the preparation of a new edition of his Report of 1919 on the ' Haematites of the Forest of Dean and South Wales '.

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6. Five years have passed since, by successive additions to the establishment in 1920 and 1921, the strength of the Survey staff was increased by about 35 per cent. We desire to refer to the record of these years and to indicate the excellent results of this increase. It has enabled the Survey to open new areas for field-work and to accelerate the production of maps and memoirs without affecting the general standards of work or publication.

One consequence of these expanded operations is that the services of the Survey are becoming more widely known and more rapidly available in the interest of British industry. In particular, the resurvey of Coalfield areas has been pressed forward energetically. Several of these which greatly needed revision were put in hand and the position now is that with but few exceptions all the Coal-fields are receiving continuous attention. As a result of this and of previous work a large part of the greater Coalfield areas has been revised.[1]

The ' Report of the Director ' and relevant documents show how many are the interests which find the reports and resources of the Survey helpful. The precise questions that call for attention vary, of course, from year to year, but the ability of the Survey to give help turns upon the systematic nature of its records—even in cases where these do not appear to bear materially on economic or other interests. The standard of the work is being well maintained. It is clear to us that ' The Geological Survey and Museum ' as a State Institution has been well served by its staff in all grades. The publications of the Survey show high efficiency in the scientific and technical work involved, as well as full continuity of that close personal touch between officers of the Survey and other workers in the same or related fields, which has marked the history of this service.

7. We refer with pleasure to two noteworthy presentations to the Survey and Museum collections during the year :—

(*a*) the Lindsey Collection, and
(*b*) a part of the Allan B. Dick Collection.

The Lindsey Collection was made by the late C. R. Lindsey, Esq., B.Sc., and comprises about 8,000 mineral specimens, many of them particularly well crystallized examples of species found in Britain, and 2,000 rocks with the accompanying micro-sections. The Collection was the gift of the late Mr. Lindsey's son and daughter, Mr. Gilbert Lindsey and Mrs. Marjorie Jones. The part of the Allan B. Dick Collection presented comprises a large number of sections of rocks and minerals and was the gift of the Misses Dick.

These collections will prove of great use both for purposes of exhibition and research, and the public-spirited action of the donors is to be commended.

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[1] *See* ' Summary of Progress ' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 27–33.

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8. An important accretion to the objects that will be available for gallery exhibition, or for examination in reserve collections in the Geological Museum of the future, arises on the offer of the Science Museum to transfer to the collections of the Museum of Practical Geology such objects in the Science Museum's geological collection as the Director of the Geological Museum considers desirable. The offer was gladly accepted, and the Director of the Science Museum has agreed to retain the objects until accommodation becomes available for them in the Museum of Practical Geology.

9. In regard to the question of the detection of underground deposits by gravitational means, already referred to in our last two Reports, we desire to place on record our further indebtedness to the Anglo-Persian Oil Company for inviting two officers of the Survey to visit Persia as their guests and there to study the work of the Eötvös Gravity Torsion Balance in the field. This valuable opportunity for acquiring further information was welcomed, and Dr. W. F. P. McLintock and Mr. J. Phemister of the Geological Survey staff visited Persia in the spring of 1926. A report of these two officers on their visit appears as an Appendix to the 'Summary of Progress of the Geological Survey for 1926'.

We are in general agreement with the conclusions arrived at by the two Survey officers, and are of opinion that it would be of much advantage to make trial of these methods in known areas in Britain under such circumstances as would bring out the possibilities and the limitations of gravitational survey appliances for geological investigations here.

10. On a reference as to the desirability of altering the normal age limits for appointment as 'Geologist' from '21 to 30' to '21 to 26,' we advised that the upper age limit should be kept at 30.

11. In continuation of last year's work in regard to soil mapping we record that a further conference between soil experts and geological surveyors was held in the spring of 1926, and that later in the year certain soil experts and geologists again worked in concert in two areas, one in England and one in Scotland, in an endeavour to make the geological drift mapping of greater assistance to agriculturists.

12. It was with considerable satisfaction that we noted the terms of Section 23 of the Mining Industry Act, 1926. The provisions of that Section will in many ways facilitate the work of the officers of the Geological Survey and increase the value of its records. For instance, under this section of the Act[1] any person who proposes searching for minerals by means of a shaft or borehole intended to reach to a depth of more than one hundred feet below the surface is required to give notice of his intention to the Committee of the Privy Council for Scientific and Industrial Research. Further, such a person is expected to keep a journal of the shaft or borehole, to retain specimens of the strata passed through, and

[1] Quoted in full in 'Report of the Director', p. 26.

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to allow any officer appointed by the Committee free access at all reasonable times to the shaft or borehole, the journals thereof, and the specimens obtained. Provision is made in the Act for treating the information so acquired as confidential for a period if desired.

Though the measure is limited to sinkings for minerals and does not apply to those for water, it is nevertheless to be welcomed as a definite advance in the procedure for collecting information from sinkings and borings as recommended in our First Annual Report (Report for the Year 1920).

13. Under the arrangements governing the retirement of members of the Geological Survey Board, three of our colleagues retired at the end of 1925—Professor W. S. Boulton, Professor J. W. Gregory, and Mr. F. Merricks—and were succeeded from the beginning of 1926 by Professor T. J. Jehu, Dr. T. Franklin Sibly, and Mr. Humphrey M. Morgans.

We desire to take this opportunity of placing on record our regret at losing the assistance of Professor Boulton, Professor Gregory, and Mr. Merricks. Throughout their membership the services of these three gentlemen, by reason of their knowledge, experience and judgment, have been of high value in the work of the Board.

14. The programme of field work for 1927 is :—

(*a*) Continuation of the primary six-inch survey of the North of Scotland, Midland Districts of England, and London District, and minor revisions in the Ramsgate, Dover, Sudbury, and Moreton in the Marsh Sheets.

(*b*) Revision of the primary six-inch survey of Fifeshire, Lanarkshire, Ayrshire, Northumberland, Cumberland, Lancashire, Yorkshire, and South Wales.

(*c*) Continuation of investigation of underground water supplies and collection of records of borings with examination of specimens from them. Investigation of mineral resources.

15. We regard it as most unfortunate that the public had again to be excluded from the Museum of Practical Geology in order that further structural repairs might be carried out on the building. This second period of closing extended from 22nd February to 19th April, 1926. We trust that, inadequate and unsuitable as the present building is for its purposes, there will not again be any necessity for closing the Museum before its transference to new quarters.

16. Last year we ventured to express the hope that all possible progress would be made with the erection of the new building for the Geological Survey and Museum at South Kensington. It was, therefore, with the greatest concern that we learned that, owing to financial considerations, no provision had been made for this purpose in the 1926–27 Estimates of H.M. Office of Works, and that similar necessities apply to the Estimates for 1927–28. In

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successive reports we have referred to the urgency of the need for the new building, and this is, we believe, fully recognised.

17. Throughout its history of more than ninety years the Geological Survey has been engaged in publishing in the form of maps, memoirs, etc., information with regard to the mineral resources of Britain, partly in advance of commercial exploitation, and partly as growing exploitation has augmented, confirmed, or modified existing knowledge. This relates to coal, iron and other metals, building stones and road metals, refractories, cements, and other raw materials of industry; it concerns also the basic information required by civil, sanitary, road, railway, mining and water engineers.

Valuable as the published information is, it can represent no more than a summary of facts and conclusions drawn from the vast mass of data collected by the officers in the field. The collected data constitute a great storehouse of records and specimens which have been accumulating in the Offices and Museum. In getting together this material the Survey has been most generously helped by engineers, geologists, works-managers, and other persons possessing information. The additional information thus supplied, much of which was otherwise unobtainable, has been checked and codified by the officers of the Survey.

The daily calls upon this material, increasing with each new industrial development, amply show its value to the public, and such references have already required the employment of increased staff. The Great War brought out in striking fashion the immense importance of the Survey records, when it was vital to use to the full all that was known of mineral and agricultural resources in the country, whether or not they happened at the moment to be in commercial employment. The series of 'Special Reports on the Mineral Resources' begun at this time and since continued would have been impossible but for the stored records, verified and checked in the field by the staff. These 'Reports' have in many cases given new impulse and direction to the mineral industries with which they dealt. Equally valuable service may be looked for in relation to new scientific and economic needs.

The Geological Survey and its Museum form a valuable asset in the scientific education of the country, and in the training of those who are to enter upon professional work as Mining or Civil Engineers. The Museum is the only one in London which possesses the requisite material and presents it in the form most helpful to those investigating geological questions for scientific or industrial ends.

18. The Geological Survey is thus in possession of invaluable and irreplaceable records held in trust for the nation—records contributed by past and present generations and essential for those who are to come after us. These records should be properly housed

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and made readily available for reference in national and economic interests. The existing building, although it occupies a very valuable site in an area of recent rapid commercial development, is inadequate for its purposes and is dilapidated. The erection of the new building at the earliest possible date is, in our opinion, essential for the adequate preservation and presentation of the records, for rendering them accessible in the interests of science and industry and for the progress of an institution which has hitherto played an important part in the development of the natural resources of this country and the Empire.

F. G. OGILVIE,
Chairman.

4th May, 1927.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1926

1. REPORT OF THE DIRECTOR

Field Surveys

THE districts in which field survey work was carried on by the staff of the Geological Survey during 1926 were mostly those in which they were engaged in 1925. In one respect, however, there was an important difference, as work was resumed in the primary survey of the Highlands of Scotland. This had been suspended since 1924, with the approval of the Geological Survey Board, for several reasons. The principal of these was the urgency of getting the revised areas of Scottish coalfields published with as little delay as possible. Restriction of the field work to the coalfields for a few years has had the effect of accelerating progress in that work; and it may be said that now the first revision of the Scottish Carboniferous is in an advanced state and, though much has to be done before the results are reduced and edited, and the maps and memoirs are issued to the public, sufficient progress has been made to render completion of the work fairly easy and rapid.

In Highland areas the conditions of geological mapping are somewhat peculiar. It is impossible to start early in the season if much of the ground is mountainous, and owing to the exigencies of sporting tenants it is necessary to vacate all deer-forest ground at the beginning of the autumn. The task which was taken in hand in 1926 was the completion of the survey of North Central Sutherlandshire (Sheet 108). Nearly one half of this Sheet had been surveyed when Highland work was temporarily suspended. The area, though not very mountainous, is remote and sparsely inhabited, and it was considered advisable to place part of the field unit in a camp near the centre of the ground to be surveyed. Wooden huts were erected with the permission of the proprietors, as tents are not suitable for a prolonged stay, and the climate is somewhat severe. In order to push forward the work the unit employed was strengthened by the addition of three geologists from the English staff, viz., Messrs. Wilson, Tonks and W. Anderson. Mr. Richey was District Geologist in charge and had with him Messrs. Read, Phemister, Ross and Haldane of the Scottish staff. Mr. Murray Macgregor, who knows that country well, paid a prolonged visit to the district. These measures were quite successful and by the first of August the survey was finished. In 1925 the Strath Oykell (102) and the Golspie (103)

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Sheets were issued in colour-printed form, and in 1925 and 1926 the accompanying descriptive memoirs appeared. It is now possible to publish the maps of the central part of Sutherlandshire. The Achintoul Sheet (109) was completely surveyed several years ago but could not be published till the adjacent ground in the Altnaharra Sheet (108) to the west of it had been thoroughly examined. These two Sheets can now be prepared for publication and thus the whole of Sutherlandshire and the north-east of the mainland of Scotland has been completely surveyed and the maps will soon be issued to the public. The geology of Caithness was fully described in a memoir published in 1914 accompanied by two colour-printed one-inch maps.

It is not intended to resume the primary survey of the West Highlands during 1927 as the unit to which this district is assigned has still a heavy task to perform in preparing the maps and memoirs on the Ayrshire coalfield for early completion.

Mr. Richey's unit in Lanarkshire and Peeblesshire has revised a comparatively small area of Carboniferous and Old Red Sandstone rocks during the past year, as so much of its time was spent in the Highlands. The Central Coalfield of Scotland is now completely revised and the new six-inch Sheets are published with one or two exceptions. Work has been carried on in the Douglas coalfield, which, though small, is an important source of coal and is of highly complex structure. Some work has also been done in the Muirkirk coalfield which belongs to the Limestone Coal Group. The whole of the ground in one-inch Sheet 23 (Lanark) has been revised and that map is being prepared for engraving. Dr. Read and Mr. Phemister have carried on some revision of the Lower Carboniferous and Old Red Sandstone rocks in the district around Biggar, Dolphinton and Dunsyre. These form the south-eastern rim of the Central Coalfield and when they are revised it will be possible to publish a new colour-printed edition of Sheet 24 (Peebles), which has been a desideratum for a considerable time. It is now clear that the geology of much of the ground recently revised was not well understood at the time when the existing maps were constructed.

In Ayrshire Mr. Bailey's unit has been actively engaged in completing the revision of Sheet 14 (Ayr) which includes the southern half of the Ayrshire coalfield. The rocks surveyed during 1926 are mostly in the south half of that Sheet and include Lower Old Red, Upper Old Red and Lower Carboniferous. That Sheet has now been completed along with a small area of Carboniferous in the Loch Doon Sheet (Sheet 8) which lies to the south. It will now be possible to engrave and print the two one-inch maps of the Ayrshire coalfield (22 and 14) and also to issue a colour-printed revision of the Loch Doon Sheet, of which the Silurian rocks were formerly revised by Dr. Peach and Dr. Horne.

The revision of the Alloa and Clackmannan field has been finished and the six-inch maps are passing through the press. Fifeshire has now been in hand for several years under Mr. Dinham but as yet only one six-inch map has been printed. The field survey, however, has

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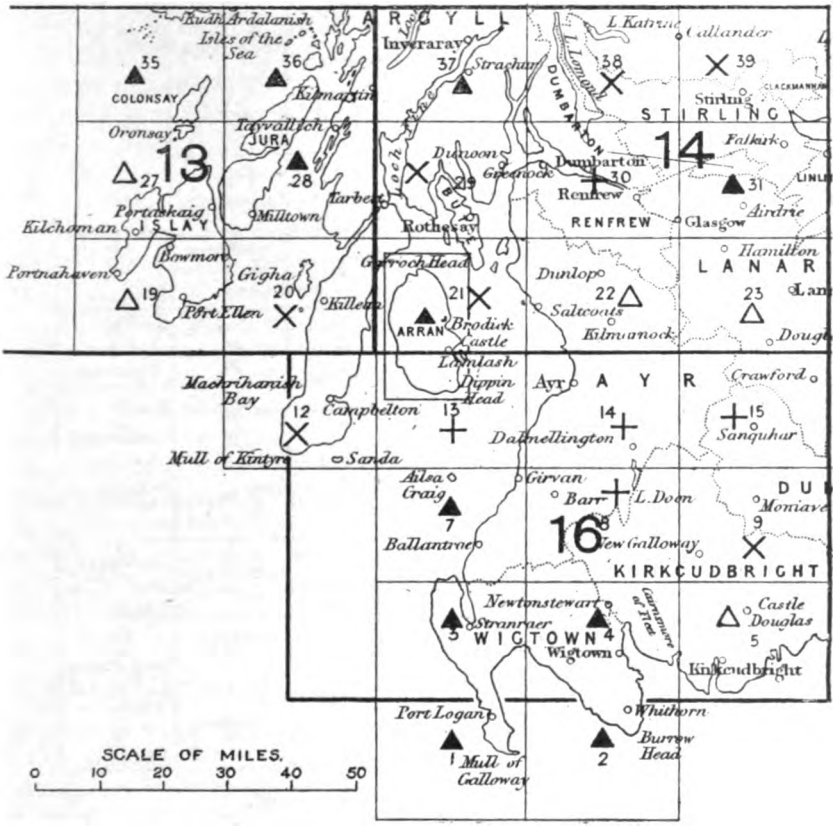
been carried eastwards along the south half of the county, where the coalfields are situated, as far as Wemyss. Small scattered areas have still to be finished but much work has been accomplished. The area is exceedingly complex: the succession is variable and the rocks are much faulted. Hitherto neither the sequence nor the structure has been well understood, and much new information has been collected during the revision. The task would have proved impossible but



▲ Published, colour-printed.
△ In the press.
+ In preparation.
× Published, hand-coloured.

FIG. 1.—*Index map of One-inch Sheets—South West of Scotland*

for the hearty co-operation of all the mining lessees and proprietors, who have never failed to place their plans and bore-records at our disposal. The revision has not yet reached a stage that makes immediate publication possible, but it is hoped that in 1927 the field work, at any rate, will be brought near completion.

In Northumberland and Durham Mr. Carruthers and his staff are working southward along the east coast, having started at

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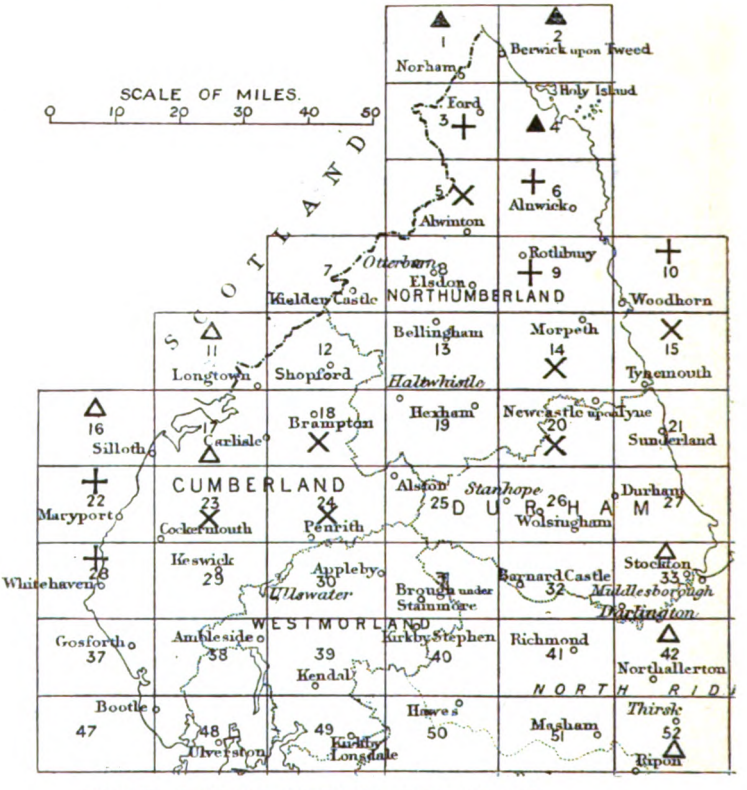
Berwick-on-Tweed, and have reached the vicinity of Morpeth. The country to the north is mostly Carboniferous Limestone and rather barren of coals, but the revision has touched the north edge of the Great Northern coalfield and the amount of detail involved has considerably increased. Although the old maps are fairly good a great deal of new information is now available. The structure of the



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▲ ,, Revised, coloured-printed, S. & D.
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\+ Revised, not yet published.
× Under revision, 1927.

FIG. 2.—*Index map of One-inch Sheets—North of England.*

ground is not very complex though there is heavy faulting and the surface is much obscured by drift. This unit has already published one memoir, three one-inch maps, and a considerable number of six-inch maps. A memoir on Belford, Holy Island and the Farne Islands is in the press. During the past year they completed the revision of one-inch Sheets 9 (Rothbury) and 10 (Woodhorn). Mr. Burnett has been engaged in revising the Cheviot Hills and has

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finished Sheet 3 (Ford) and done some work in Sheet 5 (Alwinton). A considerable area of ground revised is now ripe for publication.

The field work in Cumberland has also reached an interesting stage. Dr. Smith and his staff have published three one-inch maps of the Carlisle basin and its surroundings. During 1926 the revision of the Whitehaven and Maryport coalfield (Sheets 28 and 22), which has been in hand for five years, was effectively completed. Several of the six-inch maps are already published and others are in the press. This field is very complicated, and in fact the revision work is probably the most difficult of any coalfield work in which the English Survey staff is at present engaged; but the area is important not only as a source of coals but also as an actively worked region of iron-ore deposits. It is reasonably certain that the present revision was not only urgently required but also will stand the test of time, as no pains have been spared in collecting and studying the boring and mining information. Great interest has been taken in the work by the local mining engineers, who have given every assistance in their power.

The Brampton Sheet (18) on the east side of the Vale of Eden contains a large area of Carboniferous Limestone in which there are workable coals, as well as the west half of the small Haltwhistle coalfield which is situated almost on the watershed between Carlisle and Newcastle-on-Tyne. Mr. Trotter and Mr. Hollingworth have been working in that Sheet for two years and have nearly completed the revision. Some of the six-inch maps of that field are in the press. During the next field season the work will be continued, after Sheet 18 (Brampton) is finished, in Sheet 24 (Penrith) and Sheet 23 (Cockermouth). When these are revised practically the whole coal-bearing area of Cumberland and Westmorland will have been mapped a second time on the six-inch scale.

The Manchester Sheet (85) has absorbed the whole of the energies of the Lancashire unit during the past field season. This is one of the areas in which the surface geology counts for very little, as much of the district is occupied by alluvium, boulder-clay, and made ground, or is built over by industrial cities. The underground information, however, is very extensive, as there is a long history of active mining and there has been a considerable amount of boring both for minerals and for water supplies. The revision of this Sheet is reported finished, but the mining records have not yet been exhaustively studied, and a good deal of work has still to be done before the one-inch map can be dry-proofed. Meanwhile some of the six-inch standards are in an advanced stage. It has been proved that the sequence in this coalfield varies considerably and that there is much more faulting than was indicated on the old one-inch map.

In Yorkshire the completion of the Huddersfield Sheet (77) in 1925 enabled the staff to concentrate its attention on the Glossop Sheet (86) to the south. The rocks are mostly Millstone Grit and Lower Coal Measures and on the west they join on to the strata which are being mapped by the Lancashire unit. Consequently the geological problems attacked by these two divisions of the

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Survey are essentially the same, as there is a general correspondence in the sequence on each side of the Pennine axis. Much attention has again been directed to the study of the goniatite zones in the marine bands, which are proving very useful for purposes of correlation. Although the actual field revision is at present confined to the visible or exposed field of West Yorkshire, the new shafts and borings in the great concealed coalfield (a second edition of the

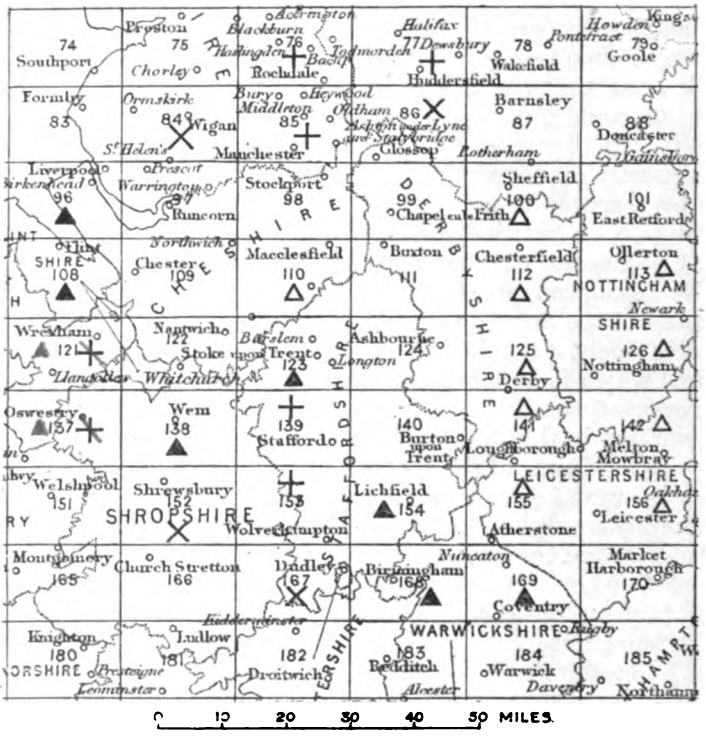

FIG. 3.—*Index map of One-inch Sheets—Midlands of England.*

memoir on this field, first issued in 1913, was published in 1926) are being kept under constant scrutiny and all developments in that most important coalfield are being carefully noted.

The principal area of field work for the unit which is engaged in the West Midlands has been the Shrewsbury Sheet (152). This is about one half revised at the close of the year. The Shrewsbury coalfield is not of great importance and has not been extensively worked, but it contains reserves of coal and is by no means exhausted.

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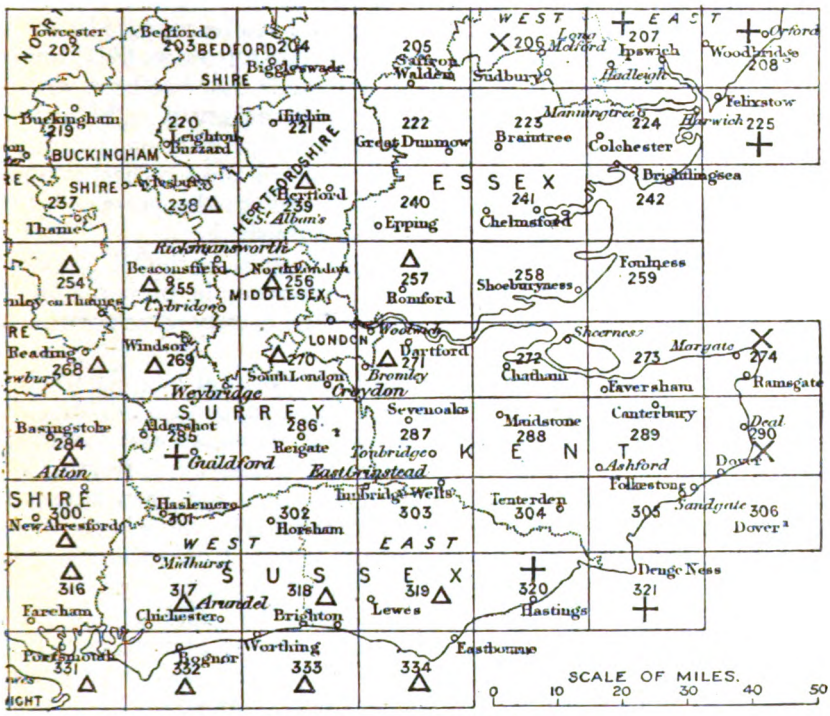
There is also a considerable variety of more ancient rocks in this neighbourhood which furnish many interesting geological problems.

It was found possible during the past year to give some attention to the South Wales coalfield, and Dr. Robertson was entrusted with the task of preparing a new edition of the memoir on Abergavenny which has been out of print for several years. As in all the coalfields under revision, in the course of this work he met with a gratifying willingness on the part of the mining engineers in this district to co-operate and the result has been that new editions of several of the



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△ ,, Revised, colour-printed, Drift.

\+ Revised, not yet published.

× Under revision, 1927.

FIG. 4.—*Index map of One-inch Sheets—South East of England.*

six-inch maps have been prepared and are now in the press. No substantial alteration has been made in the interpretation of the geology that was arrived at in the first revision under Sir Aubrey Strahan, but many additional details have been collected and some obscure points have been cleared up. A new edition of that memoir is now printing. It is intended to undertake next a new edition of the memoir on Merthyr Tydfil.

The memoir on the Iron Ores of the Forest of Dean and South Wales was also out of print, and as the original author, Dr. T. F.

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Sibly, could not spare time to revise the field data, Mr. Lloyd of the Lancashire division was instructed to visit the ground and bring the information up to date. This has been done, and a second edition of the memoir was passed for press before the close of the year.

In the London and Southern District under Mr. Dewey the revision of the Aldershot Sheet (285) on the six-inch scale has been finished by Mr. Dines and Mr. Edmunds. Although this country is well known, some interesting results have been obtained during the revision, showing that the structure is more complex than was previously suspected. This map is now ready to be engraved.

A new issue of the Hastings (320) and the Dungeness (321) Sheets is also in preparation, to accompany a memoir that has been written by Mr. Osborne White, and some of the boundary lines have been checked or altered in accordance with the latest information on the geology. Some alterations were also made in the Chichester Sheet (317), of which a new issue was passing through the press. A new edition of the Isle of Wight map was also published.

Mr. Dewey and Mr. Dines have both visited Cornwall to collect particulars of mines, ore deposits and outcrops, in preparation for revised editions of certain memoirs on that county which will soon be out of print.

It may be useful to indicate here the position of field work in the various districts. In Scotland coalfield revision has still to be overtaken in the Fife coalfield, Sanquhar, Douglas and Cumnock. In the Highlands large areas of central Inverness-shire, North Skye, the Hebrides, Orkney and Shetland have not yet been surveyed. More than one half of the Cumberland coalfields has now been revised and about one half of the Lancashire coalfield. In Northumberland Durham and West Yorkshire coalfields there remains a great deal of productive ground which needs revision. The Midland coalfields have been revised on the six-inch scale, except Shrewsbury, Coalbrookdale, Lebotwood and the Forest of Wyre. The Forest of Dean and the Bristol coalfields have not yet been mapped on the six-inch scale, but in South Wales a second revision is making progress. In the South-west, South and East of England more than sixty one-inch Sheets have now been published in colour-printed editions, after a revision which has been as detailed as the circumstances required.

Publications

A large part of the time of the staff during the winter months was spent in preparing the originals and checking the proofs, which require most careful examination. From the lists given below it will be seen that 160 sheets of maps and sections have been passing through the press during the year and as each sheet must be checked several times in each stage, a very large amount of office work has been involved.

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The following maps and memoirs were published during 1926 :—

I.—Maps

English maps published in 1926

¼ inch to 1 mile :—

Sheet 21 with 25.—Bodmin, Truro, Falmouth, Land's End, Isles of Scilly (*Solid Edition*). *Reprinted.*

1 inch to 1 mile :—

Isle of Wight Special Sheet (*Drift, New Edition*).

Sheet 1.—Norham (*Drift Edition*). Original survey by A. Geikie and W. Gunn. Revised by A. Fowler ; R. G. Carruthers, District Geologist. (*Solid Edition* published 1925.)

Sheet 2.—Berwick-upon-Tweed (*Drift Edition*). Original survey by A. Geikie and W. Gunn. Revised by A. Fowler ; R. G. Carruthers, District Geologist. (*Solid Edition* published 1925.)

Sheet 4.—Holy Island (*Drift Edition*). Re-surveyed by C. H. Dinham, G. A. Burnett, A. Fowler and R. G. Carruthers, District Geologist. (*Solid Edition* published 1925.)

Sheet 154.—Lichfield (*Solid Edition*). Re-surveyed by J. B. Hill, W. Gibson, T. C. Cantrill, E. E. L. Dixon, C. H. Cunnington, T. Eastwood and G. Barrow, District Geologist. (*Drift Edition* published 1922.)

Sheet 169.—Coventry (*Solid Edition*). Original survey by H. H. Howell. Re-surveyed by T. C. Cantrill, C. H. Cunnington, T. Eastwood, T. H. Whitehead and W. Gibson, District Geologist. (*Drift Edition* published 1922.)

Sheet 317.—Chichester (*Drift Edition*). *Reprinted with a few alterations.*

Sheet 319.—Lewes (*Drift Edition*). Re-surveyed (Chalk areas) by W. A. E. Ussher and C. Reid.

6 inches to 1 mile (coalfield maps) :—

Cumberland, 18 S.W.—Talkin. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 18 S.E.—Tindale. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 53 N.W.—Workington Harbour. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 53 S.E.—Workington. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 61 N.E.—Distington. Original survey by R. Russell, partly revised by A. Strahan. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 67 N.E. (*New Edition*).—Frizington. Original survey by R. Russell, revised by A. Strahan. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 72 N.W.—St. Bees. Original survey by W. T. Aveline. Re-surveyed by B. Smith, District Geologist.

Northumberland, 16 N.E.—Budle. Original survey by W. Gunn. Revised by C. H. Dinham ; R. G. Carruthers, District Geologist.

Northumberland, 26 N.W.—Bewick Moor. Original survey by W. Topley. Revised by G. A. Burnett ; R. G. Carruthers, District Geologist.

Northumberland, 26 N.E.—North Charlton. Original survey by W. Topley. Revised by G. A. Burnett ; R. G. Carruthers, District Geologist.

Northumberland, 26 S.E.—South Charlton. Original survey by W. Topley. Revised by G. A. Burnett ; R. G. Carruthers, District Geologist.

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Northumberland, 45 N.E.—Swarland. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, 45 S.W.—Longframlington. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, 53 S.E.—Ritton White House. Original survey by W. Topley. Revised by J. Maden; R. G. Carruthers, District Geologist.

Northumberland, 54 N.W.—Wingates. Original survey by W. Topley. Revised by J. Maden; R. G. Carruthers, District Geologist.

Northumberland, 54 S.W.—Freeholders' Quarter. Original survey by W. Topley. Revised by J. Maden; R. G. Carruthers, District Geologist.

Yorkshire, 231 N.W.—Halifax. Original survey by J. C. Ward and R. Russell. Re-surveyed by Wilfrid Edwards; C. N. Bromehead, District Geologist

Yorkshire, 231 S.W.—Southowram. Original survey by J. C. Ward, R. Russell and J. R. Dakyns. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 231 S.E.—Brighouse. Original survey by J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist

Scottish maps published in 1926

½ inch to 1 mile:—

Sheet 9.—Banffshire, East Elginshire, Northern and Central Aberdeenshire, etc.

1 inch to 1 mile:—

Sheet 7.—Girvan. Revised by Sir A. Geikie, B. N. Peach and J. Horne. (*Colour-printed edition, replacing hand-coloured edition.*)

Sheet 42 and 50.—Tiree. Surveyed by E. B. Bailey, V. A. Eyles, J. B. Simpson and A. G. MacGregor. E. B. Bailey, District Geologist.

Sheet 45.—Oban. Surveyed by B. N. Peach, R. G. Symes, J. S. Grant-Wilson, J. B. Hill, H. Kynaston and H. B. Muff. J. Horne, Assistant to the Director. (*Colour-printed edition, replacing hand-coloured edition.*)

Sheet 55.—Blair Athole. Surveyed by J. R. Dakyns, G. Barrow, J. S. Grant-Wilson, H. M. Cadell, E. H. Cunningham-Craig. J. Horne, Assistant to the Director. (*Colour-printed edition, replacing hand-coloured edition.*)

6 inches to 1 mile (coalfield maps):—

Ayshire, 21 S.E. and 22 S.W.—Troon, N. part. Original survey by A. Geikie. Revised by E. M. Anderson; E. B. Bailey, District Geologist.

Ayrshire, 22 S.E.—Symington. Original survey by A. Geikie. Revised by E. M. Anderson and V. A. Eyles; E. B. Bailey, District Geologist.

Ayrshire, 23 S.W.—Craigie. Original survey by A. Geikie. Revised by E. M. Anderson and V. A. Eyles; E. B. Bailey, District Geologist.

Ayrshire, 23 S.E.—Boydston. Original survey by A. Geikie and J. Geikie. Revised by E. M. Anderson and E. B. Bailey; C. T. Clough and E. B. Bailey, District Geologists.

Ayrshire, 24 S.W.—Middleyard, Auchencloigh. Original survey by J. Geikie. Revised by E. M. Anderson and A. G. MacGregor; E. B. Bailey, District Geologist.

Ayrshire, 27 N.W.—Troon, S. part. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.

Ayrshire, 27 N.E.—Monkton. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.

Ayrshire, 27 S.W.—Prestwick. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.

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Ayrshire, 27 S.E.—Sandyford. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 28 N.W.—Tarbolton, N. part. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 28 N.E.—Mauchline. Original survey by A. Geikie. Revised by E. B. Bailey; C. T. Clough, District Geologist.
Ayrshire, 28 S.W.—Tarbolton, S. part. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 28 S.E.—Mauchline, S.W. of. Original survey by A. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 29 N.W.—Mauchline, E. of, Sorn Castle. Original survey by A. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 29 S.W.—Catrine. Original survey by A. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 33 N.W.—Ayr. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 33 N.E.—Whitletts, St. Quivox. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 34 N.W.—Annbank, Trabboch. Original survey by A. Geikie. Revised by V. A. Eyles; E. B. Bailey, District Geologist.
Ayrshire, 34 N.E.—Ochiltree, W. of. Original survey by A. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 34 S.E.—Ochiltree, S.W. of. Original survey by A. Geikie and J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 35 N.W.—Ochiltree. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 35 N.E.—Auchinleck, Lugar, Cumnock. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Ayrshire, 35 S.W.—Ochiltree Station, Skares. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.
Clackmannanshire, 133 S.W.—Menstrie. Original survey by B. N. Peach. Revised by H. H. Read and D. Haldane; M. Macgregor, District Geologist.
Clackmannanshire, 133 S.E.—Alva. Original survey by B. N. Peach. Revised by H. H. Read; M. Macgregor, District Geologist.
Clackmannanshire, 134 S.W.—Tillicoultry. Original survey by B. N. Peach. Revised by D. Haldane; M. Macgregor, District Geologist.
Clackmannanshire, 139 N.E.—Alloa. Original survey by B. N. Peach. Revised by H. H. Read; M. Macgregor, District Geologist.
Fifeshire and Kinross-shire, 32 N.E.—Forest Mill. Original survey by B. N. Peach. Revised by D. Haldane; C. H. Dinham, District Geologist.
Perthshire and Clackmannanshire, 134 S.E.—Dollar, S. of. Original survey by B. N. Peach. Revised by D. Haldane; M. Macgregor, District Geologist.
Renfrewshire, 11 S.W.—Castle Semple. Original survey by R. L. Jack. Revised by E. B. Bailey, R. G. Carruthers, C. H. Dinham and J. E. Richey; E. B. Bailey, District Geologist.
Stirlingshire, 17 S.E.—Bannockburn. Original survey by B. N. Peach. Revised by C. H. Dinham, District Geologist.

Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. These maps are not to be published. The English maps are deposited in the head office in London. The Scottish maps are deposited in the Edinburgh office.

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English manuscript Six-inch maps deposited for reference

Denbighshire, 19 N.W. (part), S.W. (part); 22 S.W. (Flint. 17*a* S.W.); 26 N.W. (part), N.E., S.W. (part), S.E.; 27 N.W., N.E. (Flint. 18 N.E.), S.W., S.E.; 29 N.W. (Flint. 20 N.W.); 33 N.W. (part), N.E., S.E.; 34 N.W., N.E., S.W., S.E.; 36 N.W. (Flint. 22 N.W.); 38 N.E., S.E.; 39 N.W., N.E., S.W., S.E.
Flintshire, 25 N.W.
Merionethshire, 8 S.W. (part); 16 N.W. (part), S.W. (part).
Northumberland, 1 S.E. (part); 3 N.E., S.W., S.E.; 5 S.E.; 6 N.W.; 7 N.E., S.E.; 8 S.E.; 12 N.W., N.E., S.W., S.E.; 12*a* S.W., S.E.; 17 N.E.; 20 S.W.; 25 N.E.; 30 N.E., S.E.; 31 N.W., S.W.; 37 N.W.
Shropshire, 5 S.E.
Wiltshire, 13 S.E.; 14 S.W., S.E.; 15 S.W., S.E.; 16 N.E. (Berks. 18 N.E.), S.W., S.E. (Berks. 18 S.E.); 20 N.E., S.E.; 21 N.W., N.E., S.W., S.E.; 22 N.W., N.E., S.W., S.E.; 23 N.W., N.E., S.W., S.E.; 26 N.E., S.E.; 27 N.W., N.E., S.W., S.E.; 28 N.W., N.E., S.W., S.E.; 29 N.W., N.E., S.W., S.E.; 33 N.E., S.E.; 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 36 N.W., N.E., S.W., S.E.
Yorkshire, 214 N.E., S.E.; 229 N.E., S.E.; 230 N.W., S.W., S.E.; 245 S.E.

Scottish manuscript Six-inch maps deposited for reference

Argyllshire, 85.
Ayrshire, 24 N.E.; 33 S.E.
Dumfriesshire, 28 N.W., S.W.; 34; 35; 36; 37 N.W., S.W.; 42; 43; 44; 45; 50; 51; 52; 56; 57; 58; 59 N.W., N.E., S.W.
Fifeshire, 40 S.E.
Haddingtonshire, 15 S.W. (*Solid*).
Kincardineshire, 6 S.W. (S.E. quarter), S.E. (S. half); 7 S.W. (S. half), S.E. (S. half); 10 N.W. (E. half), N.E., S.W. (E. half), S.E.; 11 N.W., N.E., S.W.; 15 N.W. (E. half), N.E., S.W. (E. half), S.E.; 16 N.W., S.W.; 20 N.W. (E. half), N.E., S.W. (E. half), S.E.; 21 N.W., S.W.; 25 N.W. (E. half), N.E., S.W. (E. half), S.E.; 28 N.W. (N.E. quarter), N.E.
Lanarkshire, 23 N.W., S.W.; 25 S.W.; 30; 33 N.E.; 34 S.W. and S.E.; 36 N.W., N.E.
Ross and Cromarty, 24 N.W. (Sheet now complete).
Roxburghshire, 24; 25; 26; 32; 33; 38; 39; 41 N.E., S.E.; 42; 43.
Selkirkshire, 22 N.W., S.W.
Sutherlandshire, 32 N.E., S.E. (Sheet now complete); 41 N.E., S.W., S.E. (Sheet now complete); 73; 74; 86; 89; 97; 98 and 99; 105; 106 N.W.

The following maps were in the press during the year 1926 in various stages of engraving and colour-printing and will mostly be published during 1927.

List of maps in the press at the close of 1926

English maps in the press

½ inch to 1 mile:—

Sheet 11.—Derby, Lincoln, Sheffield, Stafford (*Solid Edition*). *Reprinting.*

1 inch to 1 mile:—

London District Special Sheet (*Drift Edition*).
Sheet 76.—Rochdale (*Solid* and *Drift Editions*).
Sheet 121.—Wrexham (*Solid* and *Drift Editions*).
Sheet 137.—Oswestry (*Solid* and *Drift Editions*).
Sheet 139.—Stafford (*Drift Edition*).

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Sheet 207.—Ipswich (*Drift Edition*).
Sheet 208.—Woodbridge (*Drift Edition*).
Sheet 225.—Felixstowe (*Drift Edition*).

6 inches to 1 mile :—

Brecknockshire (*New Editions*), 47 N.W. (Mon. 11 N.W.), N.E. (Mon. 11 N.E.) ; 48 N.W. (Mon. 12 N.W.).
Cumberland, 18 N.E. ; 19 S.W. ; 25 N.E. ; 67 S.E. (*New Edition*) ; 68 N.W.
Durham, 6 N.W., N.E., S.W., S.E.
Glamorganshire (*New Editions*), 6 S.E. (Mon. 10 S.E.) ; 12 N.E. (Mon. 16 N.E.), S.E. ; 13 N.W. (Mon. 17 N.W.), S.W. (Mon. 17 S.W.).
Monmouthshire (*New Editions*), 11 S.W., S.E. ; 12 S.W. ; 17 N.E., S.E. ; 18 N.W., S.W., S.E.
Northumberland, 26 S.W. ; 32 S.E. ; 37 N.E. ; 38 N.W. ; 45 N.W., S.E., 47 N.W., S.W. ; 54 N.E.
Staffordshire, 71 S.W.
Yorkshire, 216 N.W., S.W., S.E. ; 217 N.W., N.E., S.W., S.E. ; 231 N.E. ; 232 N.W., N.E., S.W., S.E. ; 245 N.E. ; 246 N.W., N.E., S.W. ; 247 N.W., S.W.

Scottish maps in the press

1 inch to 1 mile :—

Sheet 5.—Kirkcudbright.
Sheet 19.—Bowmore.
Sheet 22.—Kilmarnock (*Solid* and *Drift Editions*).
Sheet 27.—Portaskaig.
Sheet 51.—Coll.

6 inches to 1 mile :—

Ayrshire, 24 S.E. ; 26 S.W. ; 29 N.E , S.E. ; 30 N.E , S.W. ; 34 S.W. 35 S.E. ; 40 N.W., N.E., S.E. ; 41 N.W., S.W.
Fifeshire, 37 N.W. ; 39 N.E.
Lanarkshire, 16 S.E. ; 31 S.E. ; 37 N.E.
Stirlingshire, 17 N.E. ; 18 N.W. ; 23 N.E.

II.—Vertical Sections of Strata

In addition to the maps enumerated above seven large sheets of vertical sections of the strata of the Central Coalfield of Scotland, mostly drawn from details of borings and shafts, on the scale of one inch to 40 feet, have been prepared. These serve to illustrate the series of Economic Memoirs on the Central Coalfield of Scotland and the six-inch published maps of that coalfield. Each sheet contains from ten to twenty vertical sections.

Scottish Vertical Sections published in 1926

Sheet 9.—Vertical Sections illustrating The Central Coalfield. Coal Measures showing strata above Splint Coal in Areas V. and VII. Rutherglen, Motherwell and Coatbridge Districts.
Sheet 11.—Vertical Sections illustrating The Central Coalfield. Coal Measures showing strata mainly below Splint Coal in Area V. Shettleston, Coatbridge, and Airdrie Districts.

Scottish Vertical Sections in the press at the close of 1926

Sheet 10.—Vertical Sections illustrating The Central Coalfield. Coal Measures in Areas IX, VI, and south part of VII. Hamilton, Dalserf, Wishaw, Shotts, Fauldhouse, and Armadale Districts.

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Sheet 12.—Vertical Sections illustrating The Central Coalfield. Coal Measures showing strata below Splint Coal in Area VII. Rutherglen, Motherwell, and Holytown Districts.

Sheet 13.—Vertical Sections illustrating The Central Coalfield. Millstone Grit and Upper Limestone Group, along south and east borders. Areas IV, IX, VI and II.

Sheet 14.—Vertical Sections illustrating The Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series in Areas IV and VIII. Paisley, Giffnock, and East Kilbride.

Sheet 15.—Vertical Sections illustrating The Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series, along south and east borders. Areas IX, VI and II.

III.—Memoirs

The following list shows the memoirs published during the year 1926. The work done on them has been mainly the correction of proofs and preparation of indexes.

English Memoirs published in 1926

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1925. 211 pp.; 12 plates; 24 text-figures. 1926. Price 4s. 6d. net.

The Concealed Coalfield of Yorkshire and Nottinghamshire. *Second Edition.* By G. V. Wilson, B.Sc. 283 pp.; 5 plates; 3 text-figures. 1926. Price 8s. net.

Wells and Springs of Dorset. By W. Whitaker, B.A., F.R.S., and Wilfrid Edwards, M.A. 119 pp.; 8 text-figures. 1926. Price 3s. 6d. net.

The Geology of the Country around Oxford. (Explanation of Special Oxford Sheet.) By T. I. Pocock, M.A. With contributions by H. B. Woodward, F.R.S., and G. W. Lamplugh, F.R.S. *Second Edition.* By J. Pringle. With contributions by K. S. Sandford, M.A., D.Ph., and C. J. Bayzand, M.A. 191 pp.; 4 plates; 12 text-figures. 1926. Price 4s. net.

The Geology of Berwick-on-Tweed, Norham and Scremerston. (Explanation of one-inch Sheets 1 and 2: England.) By A. Fowler, M.A., B.Sc. 58 pp.; 2 plates; 1 text-figure. 1926. Price 1s. 6d. net.

The Geology of the Carlisle, Longtown and Silloth District. (Explanation of one-inch Sheets 11, 16 and 17: England.) By E. E. L. Dixon, A.R.C.Sc., B.Sc., J. Maden, M.Sc., F. M. Trotter, M.Sc., S. E. Hollingworth, M.A., B.Sc., and L. H. Tonks, M.Sc. 113 pp.; 4 plates; 4 text-figures. 1926. Price 2s. 6d. net.

The Geology of the Country near Lewes. (Explanation of one-inch Sheet 319: England.) By H. J. Osborne White. 97 pp.; 4 plates; 11 text-figures. 1926. Price 2s. 6d. net.

Scottish Memoirs published in 1926

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1925. *See above.*

The Economic Geology of the Central Coalfield of Scotland, Area V. Glasgow East, Coatbridge, and Airdrie, with Chryston, Glenboig, Greengairs, Slamannan, Caldercruix and Salsburgh. By C. T. Clough, M.A., LL.D., F.R.S.E.; L. W. Hinxman, B.A., F.R.S.E.; W. B. Wright, B.A., F.G.S.; E. M. Anderson, M.A., B.Sc.; R. G. Carruthers, F.G.S. With contributions from R. Kidston, LL.D., F.R.S.; G. W. Lee, D.Sc., F.R.S.E. *Second Edition.* With additions by M. Macgregor, M.A., B.Sc., F.R.S.E. 171 pp.; 13 plates; 7 text-figures. 1926. Price 5s. net.

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The Geology of Strath Oykell and Lower Loch Shin (South Sutherlandshire and North Ross-shire). (Explanation of one-inch Sheet 102 : Scotland). By H. H. Read, D.Sc., A.R.C.Sc., J. Phemister, M.A., B.Sc., and G. Ross, B.Sc. With contributions by C. H. Dinham, B.A., and M. Macgregor, M.A., B.Sc. 220 pp. ; 2 plates ; 7 text-figures. 1926. Price 6s. net.

The following list shows the memoirs in the press at the close of the year 1926. These memoirs will be published in 1927.

English Memoirs in the press at the close of 1926

Special Reports on the Mineral Resources of Great Britain :—
Vol. X.—Iron Ores : The Haematites of the Forest of Dean and South Wales. *Second Edition.*
Palaeontology. Vol. I. Part 5. Plectambonites and some Allied Genera.
The Geology of the South Wales Coalfield. Part II. The Country around Abergavenny. (Explanation of one-inch Sheet 232 : England and Wales.) *Second Edition.*
The Geology of the Southern Part of the South Staffordshire Coalfield (South of the Bentley Faults).
The Geology of Belford, Holy Island, and the Farne Islands. (Explanation of Sheet 4 : England.)
The Geology of the Rossendale Anticline. (Explanation of one-inch Sheet 76 : England).
The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121 : England.) Part I. Lower Palaeozoic and Lower Carboniferous Rocks.
The Geology of the Country around Ipswich. (Explanation of one-inch Sheet 207 : England.)

Scottish Memoir in the press at the close of 1926

Oil Shales of the Lothians. *Third Edition.*

The following list shows the memoirs which were in preparation during the year ; the manuscripts are not yet completed or require revision and editing before they can be sent to the printer.

English Memoirs in preparation but unfinished

Wells and Springs of Derbyshire.
Wells and Springs of Gloucestershire.
Records of London Wells. *Second Edition.*
Wells and Springs of Somerset.
Wells and Springs of Sussex. *Second Edition.*
Wells and Springs of Warwickshire.
Wells and Springs of Worcestershire.
The Geology of the Country around Huddersfield. (Explanation of one-inch Sheet 77 : England.)
The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121 : England.) Part II. Coal Measures and Newer Formations.
The Geology of the Country around Oswestry. (Explanation of one-inch Sheet 137 : England.)
The Geology of the Country between Stafford and Market Drayton. (Explanation of one-inch Sheet 139 : England.)

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The Geology of the Country around Wolverhampton. (Explanation of one-inch Sheet 153: England.)
The Geology of the Country around Sudbury. (Explanation of one-inch Sheet 206: England.)
The Geology of the Country around Woodbridge and Felixstowe. (Explanation of one-inch Sheets 208 and 225: England.)
The Geology of the Country around Moreton in the Marsh. (Explanation of one-inch Sheet 217: England.)
The Geology of the Country between Ramsgate and Dover. (Explanation of one-inch Sheets 274 and 290: England.)
The Geology of the Country around Aldershot. (Explanation of one-inch Sheet 285: England.)
The Geology of the Country around Hastings and Dungeness. (Explanation of one-inch Sheets 320 and 321: England.)
Catalogue of Geological Photographs suitable for educational purposes.

Scottish Memoirs in preparation but unfinished

The Economic Geology of the Stirling-Clackmannan Coalfield.
The Geology of Arran.
The Geology of Tiree. (Explanation of one-inch Sheets 42 and 50: Scotland.)
The Geology of the Country around Kilmarnock. (Explanation of one-inch Sheet 22: Scotland.)
The Geology of Coll, Ardnamurchan and Western Mull. (Explanation of one-inch Sheet 51: Scotland.)

In reference to the above lists of publications which have been in hand during the past year it may be remarked that practically all of the maps are new and based on a revised survey which has brought the information up to date of publication. Exceptions to this rule are the two Scottish Highland maps Oban (45) and Blair Athole (55) and the Girvan Sheet (7). These have been reprinted from the current hand-coloured editions without essential modification except that drift and solid are now both shown on the same map by the method of overprinting in stipple that has been in use for some years for maps of the Scottish Highlands and Southern Uplands.

The quarter-inch maps of which reprints are periodically required are in all cases brought up to date, though the changes are not usually considerable. The Land's End quarter-inch map (Sheet 21 with 25) has been reprinted by a different process from the former issue, but is otherwise little changed. Some English one-inch maps such as Chichester (317), Isle of Wight (Special Sheet), and Lewes (319) have been little modified from the hand-coloured editions; the others are all based on a complete six-inch re-survey, and, especially in the coalfields, they show much more detail and are more accurate than the old maps which they supersede. In districts where mining is important solid editions are being issued in addition to the usual drift edition. This was done by special request in the case of the Lichfield (154) and Coventry (169) Sheets, and there is no doubt that for educational purposes the expense of the solid edition can be justified.

The most recent one-inch maps have mostly vertical and horizontal sections which make them much more easily understood by those who do not know the district and its geology. Various types of 'solid' and 'drift' maps are being tried in order to find

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out what is the most satisfactory ; and where both editions are issued it is possible to make them supplement one another by emphasising the special features which each edition is meant to represent.

The six-inch maps which are deposited in the library are much used by the public for reference ; they promise to have a wide employment as the basis for agricultural soil surveys, and experiments are being made to get copies of them cheaply by photography, as the expense of drawing and colouring copies by hand is too great to render their use really popular where considerable numbers of them are desired.

Special Reports on British Mineral Resources

No new volumes have been added to this series, but a second edition of the Report on the Iron Ores of the Forest of Dean and South Wales was on the eve of publication at the close of the year. Some of the other volumes are nearly sold out and steps will have to be taken to republish them after bringing the information and statistics up to date. Visits of inspection to active metalliferous mines were paid in several districts of Scotland and England and reports prepared which will be useful for reference. In Cornwall Mr. Dewey and Mr. Dines have kept in touch with recent developments in mining for tin and tungsten, and Dr. Bernard Smith has paid frequent visits to the haematite mines of Cumberland and North Lancashire.

Water Supply Memoirs

One memoir on county water-supplies was issued during the year—'The Wells and Springs of Dorset.' No other volume is at present in the press but volumes on Somerset, Warwickshire and a second edition of the volume on Sussex are getting ready and may be printed during 1927. Mr. Stephens of the Yorkshire division has been collecting information on Derbyshire ; and manuscripts on the water-supply of Gloucestershire and Worcestershire by Mr. L. Richardson await editing and reduction to final form before they can be printed. Great care is being taken to verify the boring records, sites of bores, and the statistics for these memoirs. The number of enquiries received from water engineers, boring firms and private individuals in search of water-supplies is very great and a large amount of information comes to hand from such sources. Many borings for water provide most useful geological data, and numerous visits to such borings are made by the staff every year to check the records and collect particulars that would otherwise be lost or doubtful.

Inspection of Bores

By Section 23 of the Mining Industry Act of 1926 the following provision was made for the notification of borings and sinkings and

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for giving access to the works by members of the staff of the Geological Survey of Great Britain :—

"23.—(1) Before any person sinks, for the purpose of searching for or getting any minerals, a shaft or borehole intended to reach a depth of more than one hundred feet below the surface, he shall give to the Committee of the Privy Council for Scientific and Industrial Research (hereinafter referred to as "the Committee") notice in writing of his intention to do so, and any person who for such a purpose sinks any such shaft or borehole shall keep a journal thereof, and shall retain for a period of not less than six months such specimens of the strata passed through as may have been obtained in the course of the sinking thereof, either as cores or fragments, and shall allow the Committee, or any officer appointed by them, to have free access at all reasonable times to any such shaft, borehole or core, to inspect and take copies of the journals of such shafts or boreholes, to inspect all specimens so obtained and kept, and to take representative specimens of any such cores.

(2) If the person sinking any such shaft or borehole as aforesaid gives notice in writing to the Committee requiring them to treat as confidential any copies of journals or specimens so taken by the Committee or by any officer appointed by them, the Committee shall not allow those copies or specimens to be published or shown to any person not being an officer of the Department of Scientific and Industrial Research, except with the consent of the person sinking such shaft or borehole :

Provided that, if at any time the Committee give notice to any person from whom such consent is required that, in their opinion, his consent is unreasonably withheld, then that person may, within three months after such notice is given, appeal to the Railway and Canal Commission, but if at the expiration of that period no such appeal has been made, or if after hearing the appeal the Commission do not make an order restraining them from doing so, the Committee may proceed as if such consent had been given.

(3) The owner, agent, or manager of every mine shall allow the Committee or any officer appointed by them to have free access at all reasonable times to all underground workings, and shall supply to the Committee or to any such officer as aforesaid such information and such specimens of seams or strata sunk through or opened out at the mine as may be reasonably required by the Committee.

(4) If any person sinking any shaft or borehole, or the owner, agent or manager of any mine fails to comply with any obligation imposed on him by the foregoing provisions of this section, he shall, in respect of each offence, be liable on summary conviction to a fine not exceeding fifty pounds.

(5) Any officer appointed by the Committee shall have the same rights as to the production and examination of plans and sections kept in pursuance of sections twenty or twenty-one of the Coal Mines

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Act, 1911, or sections fourteen or nineteen of the Metalliferous Mines Regulation Act, 1872, as are by those Acts conferred on inspectors, and those Acts shall apply accordingly."

Shortly after the passing of the Act a circular was prepared and circulated to mine managers, directors of mining companies, mining engineers and firms boring for minerals in Great Britain. This circular quoted the paragraphs of the Act which referred to boring and sinking and offered a few suggestions regarding the preservation of specimens and the keeping of the journals. The circular was well received and appears to have served its purposes as numerous applications were made by mining firms to be supplied with additional copies.

Steps are being taken to ensure that every important bore and shaft will be visited as often as seems necessary by an experienced officer who will secure that no information likely to be of permanent geological value will be lost and that a satisfactory suite of specimens will be obtained during the course of the work and registered and preserved in the collections of the Geological Survey.

Up to the passing of the Act the Geological Survey had no authority to inspect borings or to obtain copies of the records. Difficulties were encountered, though not so often as might have been expected; by long experience, and very largely from personal knowledge of the principal mining and boring engineers, it proved possible in the vast majority of cases to get the information that was really necessary for the prosecution of our work. But many borings were begun and completed before we had knowledge of them, and especially in new or unproved ground it is essential that the cores should be inspected and the records checked while the work is in progress. Many mistakes might have been corrected and considerable expenditures of money avoided had boring records in former years been subjected to a thoroughly scientific scrutiny before it was too late. It is hoped that in future this loss of valuable information will be reduced to a minimum; and when an adequate staff has been provided and trained for bore inspection the authenticity and value of the records will be greatly increased.

In many parts of England and Scotland our principal source of information regarding the deeper rocks and their structure is wholly derived from bores, shafts and mines. In such districts as the concealed coalfield of Yorkshire and Nottinghamshire, the Lancashire coalfield and the Fifeshire coalfield, the main task of the geologist who is making a 'solid' map is to obtain and interpret such records. Often the surface information has practically no bearing on the deep geology.

The bore records are checked, drawn out in vertical columns to a standard scale, and when placed side by side give definite information regarding the sequence of strata and the disposition of the beds that is absolutely indispensable. In Scotland in many

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mining districts there are thirty or forty bores to every square mile. The collection of boring records in our Scottish office has been estimated to contain nearly thirty thousand bores. In most districts of England boring for minerals is not so prevalent, but in the South and East of England there are very numerous bores for water and the Geological Survey has published eighteen volumes on Water Supply which contain the records of thousands of bores. Many of our other memoirs, such as those on Liverpool, the concealed coalfield of Yorkshire, Lichfield, Coventry, etc., have an appendix or special chapter dealing with the principal bores in the district. The number of enquiries regarding these bore records which are received in our headquarters and branch offices is very great and the establishment of a standard system of bore registration will undoubtedly be of great service to the mining industry.

Much of the information thus obtained has to be treated as confidential as it is not in the interest of the parties that executed the work that the particulars should be made public; but in most cases when business arrangements have been completed the information is released; and in any case the knowledge, though confined to the staff of the Geological Survey, can be used to keep the maps and memoirs free from avoidable error and the records may settle many obscure points that seem to have only a distant relation to the practical issues that are immediately involved.

Scientific Committees

In several British coalfields Research Committees have now been set up under the auspices of the Department of Scientific and Industrial Research to study problems especially connected with the local deposits of fuel and refractories. A member of the staff of the Geological Survey has been appointed to each of these committees and serves not only as a geologist especially conversant with that district but also maintains a connexion between the Survey and the Research Committee. The following officers serve on these committees:—Mr. J. Allen Howe (North Staffordshire), Mr. W. B. Wright (Lancashire), Mr. R. G. Carruthers (Northumberland and Durham), Mr. C. E. N. Bromehead (South Yorkshire and Nottinghamshire & Derbyshire), and Mr. Murray Macgregor (Scotland). Especially in relation to the structure of coalfields and correlation of seams in one or in several adjacent coalfields these officers may be able to render valuable service.

Mapping of Agricultural Soils

In last year's Report (p. 10) some particulars were given of a scheme of soil-mapping which was under consideration by a committee presided over by Sir Thomas Middleton. An endeavour has been made to adopt the methods and symbols recommended by this committee in the field survey of various districts during the past year. The following notes have been prepared by Mr. Howe and

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Mr. Macgregor on the work done in various areas in England and in Scotland during the past year. As yet the results are merely preliminary but it is expected that on further trial it may be possible to render our drift maps more useful to the agriculturist and the soil expert.

Mr. Howe reports that :—

The investigation of methods of preparing six-inch geological maps in a manner that will provide the utmost possible information to agriculturists consistent with the means and time available to the field geologist has been continued this year.

In the Midlands District Mr. Pocock was occupied five days in combined field work with four agriculturists, two from Harper Adams College and two from Bangor. In so far as the soil characteristics are determinable in the field, there appeared to be close agreement between the agriculturists and the geologist.

In all the districts the instructions circulated at the beginning of the field season regarding the observation and recording of soil characteristics have been carried out. Since a large part of the field work now in hand lies in mining and densely populated areas, as in Lancashire and Yorkshire, or in regions ill-suited for agriculture, as in parts of Cumberland, there has been little scope for development in the maps of these regions.

After a prolonged discussion as to the type of field-auger to be used, two models have been adopted provisionally and have been employed in some districts.

Mr. Tonks reports that the Manchester moraine belt is so complex that auger boring on a 100 yards grid system would be necessary to adequately prove the soil.

Mr. Jones considers that in his Coal Measures ground the drift mapping represents the soil conditions very closely ; but in the area underlain by the red rocks, much of it covered by peat resting on fluvio-glacial sand, laminated clay and boulder-clay, the drift mapping does not conform so well with the distribution of the soil types. Here auger borings have not been practicable during the field season on account of the crops, and he suggests that in such cases it might be undertaken during the winter months if it were thought desirable.

In Mr. Trotter's ground fourteen typical soil samples have been collected at sites of his selection by Mr. G. S. Wood, of Brampton, who proposes to make a physical analysis and estimate of acidity of the samples in time for inclusion in the Memoir (Sheet 18).

With some maps it would be possible to make a rough flimsy, at the time of making the standard, on which the boundaries of the different soil types could be drawn. Dr. Robertson has prepared three trial flimsies for his own Standards. They show that while in many cases the geological map should be quite sufficient for the agriculturist, there are cases in which the soil outline traced by the geologist from his own map would convey the facts more completely and readily to the agriculturist.

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Certain photo prints of six-inch geological maps have been supplied and the subject is still under consideration.

Mr. Macgregor reports that :—

Regulations for the mapping and recording of superficial deposits were drawn up and copies of these were distributed to the field staff. The geological classification hitherto in use was retained but special attention was given to determining boundaries as accurately as possible. Natural and artificial cuttings through superficial materials were carefully examined and noted, and by the use of standard symbols or short written notes variations of texture, etc., occurring within the different deposits, were indicated. The drift mapping was thus rendered more uniform. Light augers were requisitioned for the purpose of sampling the soils over badly exposed areas but they were not available till near the close of the field-season.

The only request for collaboration in field work was made by Dr. Ogg, of the East of Scotland Agricultural College. Mr. Simpson was detailed for a few days to assist him in mapping the drift of six-inch Sheet Haddington 15 N.W., the drift map to serve as a basis for a more detailed soil map by Dr. Ogg.

The chief areas in which officers were at work during 1926 included such different districts as Central Sutherland, West Fife, and South Ayrshire. In Sutherland nothing was attempted beyond mapping alluvial flats, peat, morainic drift and moraines, but notes were made wherever sections were exposed showing the thickness of the superficial deposits. In Fife the standard symbols were made use of and proved quite satisfactory, and records of the materials found in natural sections, excavations and borings have been collected. Much of the area mapped in South Ayrshire is hill pasture and here careful notes have been taken of general soil characters, which can be inserted on the standard copies of the six-inch sheets and used later on in the Explanatory Memoir.

In Northumberland the staff has been working chiefly on boulder-clay areas with occasional spreads of sand and gravel. In the Cheviot Hills again, where a good deal of revision work has been done, the ground is occupied by rock and moorland. The standard symbols have been used by all the surveyors in these areas and here also boundaries separating the various superficial deposits—peat, alluvium, sand and gravel, boulder-clay, etc.—have been carefully determined.

Geophysical Methods of Survey

Much attention has been directed of recent years to the adaptation of geophysical methods of investigation to the problems of geological surveying. Of these methods perhaps the most widely known is the use of the Eötvös balance. By the kindness of Sir John Cadman and the Directors of the Anglo-Persian Oil Company, Dr. McLintock and Mr. J. Phemister had the opportunity of visiting Persia and joining the field parties using these methods for the Anglo-Persian Oil Company. A report by these geologists on the uses of the Eötvös

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balance is printed as an Appendix to the 'Summary of Progress' (pp. 168–196). Many enquiries regarding the principles and practice of this method of surveying have been received and it is possible that the Geological Survey will institute a series of field trials in order to ascertain how far it may be employed with advantage in the problems that arise in Great Britain.

Collaboration

The Geological Survey of Great Britain continues to receive very valuable support and assistance from many academical and private British geologists. Of these we may mention that Prof. O. T. Jones of Manchester is now correcting proofs of a Palaeontological Memoir on 'Plectambonites.' This will form the fifth and concluding part of Volume I of our Palaeontological Memoirs. Prof. P. G. H. Boswell of Liverpool University is correcting proofs of a memoir on the Geology of Ipswich and has also contributed memoirs on the Woodbridge and Felixstowe area, and the Sudbury area, which are not yet printed. Dr. G. W. Tyrrell of Glasgow University is still engaged on the completion of his manuscript on the 'Geology of Arran.' Dr. R. Campbell of Edinburgh has furnished a revision of the six-inch maps of the Stonehaven Sheet (Scotland 67), which is to be used as the basis for a new colour-printed edition of that one-inch sheet. Miss Muir-Wood has in hand the preparation of a memoir on *Productus* which will be issued as one of our Palaeontological Memoirs. Mr. L. Richardson has completed the manuscript of a Sheet description of the Moreton in the Marsh Sheet (England 217). Mr. Osborne White, having completed a memoir on the Hastings and Dungeness Sheets (320–321), has in hand a description of the Geology of the Country around Ramsgate and Dover (Sheets 274–290). Miss E. M. Lind Hendriks is compiling a list of selected geological photographs which are suitable for educational purposes.

In addition to these we may mention that we have received assistance from Dr. G. L. Elles, Cambridge (graptolites), Prof. W. H. Lang and Mr. J. Walton, Manchester University (fossil plants), Mr. S. S. Buckman (ammonites), Dr. L. F. Spath (ammonites), Prof. D. M. S. Watson (fossil fishes), Prof. Hawkins, Reading (echinoderms), and several other specialists.

As will be seen from the list of specimens figured and described in publications during the year 1926 our collections of fossils have been freely placed at the service of palaeontologists and palaeobotanists doing research work in Britain.

During the year 1926 the Geological Survey has lost by death two of its most distinguished collaborators. Dr. B. N. Peach died in Edinburgh on 29th January, 1926, and Mr. G. W. Lamplugh in St. Albans on 9th October, 1926. In both cases they had served on the Geological Survey staff for many years and had retired from routine Survey duties. Both were, however, actively engaged on geological work connected with the Survey's publications and placed their

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ripe experience and wide knowledge of British geology at the service of the institution to which they had belonged. Dr. Peach was engaged in preparing a series of new maps of the Silurian country of the South of Scotland, embodying the results of a revision that had been carried out in co-operation with Dr. Horne previous to 1899 but had never been published in satisfactory form. Mr. Lamplugh was carrying on his investigations on the Lower Cretaceous rocks of England and had arranged to produce a memoir or a series of short contributions containing the mature conclusions of a life-long study of that group of rocks. The work which Dr. Peach was doing is being carried forward by Dr. Horne, but Mr. Lamplugh's contributions were not in such a state at the time of his death that they will be available for publication.

Dr. Peach retired from the Survey in 1905, having served for 43 years. He was a link with the days of Murchison and retained all his mental vigour to the last. His name is associated with several classic monographs such as the Geological Survey Memoirs on 'The Geological Structure of the North-West Highlands' and 'The Silurian Rocks of Scotland.' He had an immense knowledge of the geology of Scotland; as a field worker he was unsurpassed and he trained up generation after generation of Scottish Survey geologists in methods of field work in a manner which has left its stamp on every department of field investigation in Scotland. For palaeontology he had an especial affection and his few published contributions to that subject are of great value.

Mr. Lamplugh retired from active service in 1920, at which time he held the post of Assistant to the Director in charge of Survey work in England. From 1901 to 1905 he had been in charge of the Survey in Ireland, but returned to England when that Survey was disjoined from the Survey of Great Britain. He had a wide knowledge of many departments of geology, especially Carboniferous, Cretaceous and Glacial. His principal contribution to Survey literature was the monograph on the Isle of Man, but he had edited or assisted in many other English memoirs. All his work was marked by the greatest thoroughness and accuracy and the standard which he set himself was always a very high one.

Palaeontology

England and Wales.—Specimens of fossils to the number of 8,433 have been added to the collections during the year; about 1,000 of these were acquired by presentation and by purchase. The presentations include a series of Lower Carboniferous fossils obtained in Carnarvonshire by Dr. E. Greenly, and a set of Jurassic specimens, chiefly gasteropods from the Inferior Oolite, the gift of Mr. L. Richardson. Dr. C. A. Matley presented a series of Ordovician fossils from the Lleyn district of Carnarvonshire.

The collecting in connexion with the current Survey work was carried out by Messrs. A. Templeman and S. W. Hester in Lancashire,

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Cumberland (with a part of Northumberland), Yorkshire, and Surrey. In addition to his work near Guildford and Aldershot, Mr. Hester spent some time in a search for fossils in the Netley Heath Gravels, with a view to obtaining evidence for a determination of age. Mr. Templeman made numerous visits to a boring in progress at Wokingham, and also collected from the cores of important borings at Selston Colliery and Sutton, in Nottinghamshire.

The examination of specimens obtained in the course of current Survey work has been carried out chiefly by Mr. Pringle and Mr. Chatwin. Certain groups of fossils have been sent out, as usual, to specialists. Much time has been spent in the preparation of contributions to Sheet memoirs and in the correction of manuscripts and proofs. Dr. Kitchin has given attention to curatorial work and has also been much occupied in preparing manuscripts of palaeontological monographs for printing. That by Prof. O. T. Jones on '*Plectambonites* and some Allied Genera' was sent to press.

Mr. Pringle read the proofs of the new edition of the memoir on the Special Oxford Sheet, which was published in June, and paid visits to numerous sections in the Oxford area. He examined the cores of the borings at Combe Abbey near Shilton (Warwickshire) and Selston Colliery (Nottinghamshire). He also gave assistance in the districts of Brampton (Sheet 18), Shrewsbury (Sheets 151 and 152) and Abergavenny (Sheet 232). In each case critical sections were examined by him in company with the field-geologist engaged in surveying the ground.

Mr. Chatwin visited sections at localities in the Guildford and Aldershot districts (Sheet 285) and also examined the cores of the boring at Wokingham. He studied fossils from the Eocene, Chalk and Lower Greensand of Surrey, including a large collection from the Bargate Stone. He also named many fossils from the Chalk of Norfolk and spent much time in registering Cretaceous and Tertiary specimens.

Much time has been spent in answering enquiries and in assisting research-workers and advanced students in their investigations. Sets of fossils numbering in the aggregate 2,732 specimens have been sent out on loan for the purpose of research.

SCOTLAND.—Fossils to the number of 1,823 were collected from the Carboniferous rocks of Scotland and Northumberland. The Scottish specimens came from natural exposures in Fife and Ayrshire and from borings situated in various districts.

Further exhibits of Jurassic fossils, mostly from Ardnamurchan, Argyllshire, have been added to the Geological Survey Collection in the Royal Scottish Museum.

PALAEOBOTANY

By the death of Dr. Kidston the Survey lost the services of the most experienced systematic British Carboniferous palaeobotanist. The transfer of the Kidston Collection of fossil plants to the Museum

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of Practical Geology and the unfinished state of Dr. Kidston's monograph on British Carboniferous Fossil Plants rendered it necessary to make immediate provision for the efficient prosecution of palaeobotanical work. This is now of great importance as so much of the Survey's staff in the field is engaged in mapping Carboniferous ground. In August, 1926, Dr. R. Crookall, Lecturer in Botany in Aberdeen University, was appointed to the staff as geologist with especial reference to palaeobotanical investigations. After a brief stay in the field to make himself acquainted with methods of field work he began the systematic preparation of a bibliography of Dr. Kidston's original books and papers, which is now completed. He is also occupied in preparing a complete list of the Kidston Collection with references to published descriptions, figures, etc. This work has been carried forward to an advanced stage by Mr. Chatwin, assisted by Mr. Morgan of the palaeontological department. When this catalogue is ready for publication it is hoped to resume the preparation of Dr. Kidston's monograph with a view to completing it as rapidly as possible.

Professor Lang of Manchester University has given much valuable help in the work of preparing the Kidston bibliography and catalogue, which will be submitted to him for critical revision. Dr. Crookall has also done a considerable amount of current palaeobotanical work in determining specimens sent in from the districts in which survey is being prosecuted.

Petrography

The Petrographer has continued his work, in co-operation with Mr. Richey, on the Tertiary igneous rocks of Ardnamurchan for the forthcoming memoir on the geology of Sheets 51 and 52, Scotland. Petrographical reports have been drawn up on the igneous rocks of the Oswestry District, on the basaltic lavas of Horsehay and Doseley, on the Whin Sill and other rocks in Northumberland, and on such other material as has been submitted by geologists working in the districts being surveyed. Assistance has also been given to students and others making enquiries. Miscellaneous work carried out by the Petrographer has been examination of road stones for the Road Board, and specimens submitted by the Ministry of Health, Chemical Warfare Research Department, Fuel Research Board, Hydrographic Department of the Admiralty, and other Government and public bodies.

In the Scottish Office Mr. Bailey and Mr. Eyles have completed a petrographical account of the igneous rocks and gneisses of Tiree, and substantial progress has been made by Mr. A. G. MacGregor with the descriptive petrographical work connected with the igneous rocks of Ayrshire. Dr. Read and Mr. Phemister have done some preliminary work on the igneous rocks of Lanarkshire and have commenced their petrographical account of the igneous and metamorphic rocks of Sheet 108 (Sutherlandshire).

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Dr. Tyrrell of Glasgow University, who is preparing a second edition of the memoir on the Island of Arran, has undertaken the description of the petrographical features of the rocks for that memoir.

The number of sliced rock-specimens in the collections deposited in London is as follows :—

English	13,796
Scottish	25,530
Irish	447
Foreign	2,691
Total	42,464

This represents an increase of 1,726 in the registered sliced rocks during the year. Of the corresponding sections, 715 were made in the English Office, 607 were registered to be made in Scotland, 89 have been acquired by purchase, and 315 have been presented.

In addition the Department has been enriched by the presentation of a large number of sections and microscopic preparations of rocks and minerals which formed part of the collection of the late Allan B. Dick ; also, of some 2,000 rock specimens and corresponding sections from the collection of the late C. R. Lindsey of Manchester. These presentations will be retained respectively as the Dick and Lindsey collections. Mr. Allan Dick had been an assistant in the chemical laboratory of Dr. Percy, when De la Beche was Director. He was an expert in micromineralogical technique whose opinion on obscure minerals in rock sections was held in the highest esteem by all workers in petrology.

During the year 165 sections have been loaned to private individuals for purposes of research.

Photography

England and Wales.—Mr. J. Rhodes, working mainly in the districts of N. Wales, Sussex, Staffordshire, and Yorkshire, has taken 572 photographs of geological subjects which will form part of the registered series of English photographs.

The number of registered negatives is now as follows :—

English Photographs	3,819
Photomicrographs	1,626
Miscellaneous	1,604

Mr. Rhodes has made 1,492 prints from the Survey negatives, mostly of geological views for incorporation in the reference albums, and including 59 made for the special purpose of illustrating forthcoming Survey memoirs and other works.

About 40 photographs have been taken in Scotland, principally in the neighbourhood of Stirling.

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During the year, 230 lantern slides have been made and added to the collection now in the process of formation.

The album of photographs in London and in Edinburgh has been completed during the year and brought thoroughly up to date with the corresponding descriptive accounts of each photographic view. This album is extensively used by visitors to the library. An increasing number of enlargements from Survey negatives of British scenery is exhibited in the Museum to serve as illustrations of geological processes and structures.

A catalogue of selected photographs useful for educational purposes is in preparation.

Chemistry

The number of rock-specimens registered as analysed or for analysis in this department's books at the end of 1926 is indicated as follows :—

English	332
Scottish	456
Irish	2
Welsh	55
Others	46
Total	891

Of these, twenty-two have been reported during the year and nine are nearing completion. Fourteen qualitative examinations have been made for Survey officers, and many enquiries from various sources have been received.

For the Fuel Research Board, some work was undertaken relative to the determination of phosphorus in coal ashes.

Museum of Practical Geology

The Museum had to be closed to the public from February 22nd to April 19th for the installation of additional supports to the roof and side-galleries. The total attendance for the incomplete year was 15,247.

Progress has been made with the reorganisation of the exhibits on the ground floor. The lighting there is now so poor that small specimens cannot profitably be shown. Large numbers of them have been removed to store and their places taken by educational exhibits of maps and enlargements of Survey photographs. These exhibits have attracted considerable attention and have resulted in increased sales of photographs and lantern-slides.

Cataloguing and registration have been kept up to date; the Maw Collection of Clays has been card-indexed and the collection of the late Mr. Allan B. Dick, presented by the Misses Dick, has been registered. The important Lindsey Collection, presented in October by Mrs. Jones and Mr. Gilbert Lindsey, and comprising 8,000 mineral

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specimens and 2,000 rocks with accompanying micro-sections, was safely transferred from Manchester to the Museum, where it is housed in the cabinets which were included in the gift.

In the Mineral Department, 135 specimens were registered and card-indexed, 967 specimens in the Ludlam Collection were catalogued and 177 rock-sections were cut. Exhibits to illustrate Volume XXIX of the ' Special Reports ' on Iron Ores have been prepared.

Library.—The additions to the Library during the year comprise 282 volumes of independent works, 2,919 volumes and parts of serials, 596 maps and 193 pamphlets. In the same period 263 volumes were bound, 717 maps were mounted and 450 lantern-slides and photographs were supplied to the public ; 523 Geological Survey photographs were added to the collection.

The transfer of 7,000 volumes and 1,500 maps from the mezzanine floor to the lower annexe and first basement room has been completed. The number of special enquirers who signed the enquiry book was 2,878.

List of Donations during the year 1926

ABELSON, WALTER, ESQ.—A large, cut yellow sapphire.

ASHMORE, G. P., ESQ., A.R.S.M., M.I.M.M.—A series of specimens of diamond-bearing gravel, bed-rock clay, pebbles and concentrates from the Gold Coast ; zinc-blende from Mexico and cassiterite from Spain.

BACON, T., ESQ.—Concretion simulating a fossil from Derbyshire.

BARKER, E. J. H., ESQ.—Specimen of garnetiferous sandstone from Kilindini Harbour, Mombasa, East Africa.

BOXHALL, W., ESQ., J.P.—Specimen of apatite with quartz, orthoclase and tourmaline from Calkarrow, St. Austell, Cornwall ; large specimen of banded tourmaline from Dorothy Mine, St. Stephens, Cornwall.

COTTERELL & SONS, MESSRS. A. P. I.—Ammonites from the Upper Lias of Cudworth, Somerset.

COYSH, COMMANDER W. H., R.N., D.S.O.—Specimen of molybdenite from half-way between Kena and Kosseir (Red Sea).

DANGAR, R. R., ESQ.—Silver ore specimens from Tulloch Silver Mine, Rockvale, New South Wales.

DAVID, PROFESSOR SIR T. EDGEWORTH, K.B.E., F.R.S., F.G.S.—Specimen of hortonolite from the Transvaal ; ' Darwin glass ' from the west coast of Tasmania.

DAVISON, E. H., ESQ., B.Sc., F.G.S.—Rock specimens from Tolgus Shaft, Redruth, Cornwall.

DICK, THE MISSES.—A large number of sections of rock and minerals forming part of the collection of the late Allan B. Dick, Esq.

DRUGMAN, DR. J.—Simple crystals of andesine, Carlsbad and Manebach twins ; also twinned crystals of quartz.

GREENLY, EDWARD, ESQ., D.Sc., F.G.S.—A series of Lower Carboniferous fossils from Carnarvonshire.

HEWITT, H. DIXON, ESQ., F.I.C.—A series of Lower Greensand fossils from boulders in the Thetford Glacial Gravels at Thetford Warren, Norfolk.

JOHNSTON, MISS M. S., F.G.S.—A series of choice miscellaneous fossils.

JONES, MRS. MARJORIE, and GILBERT LINDSEY, ESQ.—A collection of 8,000 minerals, 2,000 rocks with micro-slides and cabinets, being the collection of the late C. R. Lindsey, Esq., B.Sc.

LEWIS, S. J., ESQ., D.Sc.—Specimen of baddeleyite from South America.

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MATLEY, C. A., Esq., D.Sc., F.G.S.—A series of Ordovician fossils from the Lleyn District of Carnarvonshire; also specimens of igneous rocks from Jersey.

PENROSE, J. D., Esq.—Samples of oil from Shirebrook Pit, Notts, and No. 3 Well, Hardstoft; shale specimen from Ashford, Derbyshire.

POPHAM, J. L., Esq., F.G.S.—Specimen of tin-ore from Beatrice Mine, Malay States.

PORTER, G. R. H., Esq.—Two specimens of apatite from Carn Marth, Cornwall; specimen of pyrite from the New East Pool Mine, Cornwall.

RICHARDSON, L., Esq., F.R.S.E., F.G.S.—A series of Jurassic fossils, chiefly gasteropods from the Inferior Oolite.

ROGERS, INKERMAN, Esq., F.G.S.—Seven specimens of plant-remains from the Devonian (Baggy Beds and Hangman Grits) of North Devon.

RUTHERFURD, W. G., Esq.—Polished pebble of zoisite amphibolite from Alassio, Italy.

SANDISON, R. C., Esq.—Chromite concentrate from Unst, Shetland.

SCHETELIG, Professor J.—Thirty-eight large hand specimens of igneous rocks from the Fen district, Telmark, Southern Norway.

SMITH, STANLEY, Esq., M.A., D.Sc., F.G.S.—Three corals from the Carboniferous Limestone of Eskett Quarry, Cumberland.

STEBBING, W. P. D., Esq., F.G.S., F.S.A.—Nine specimens of fossiliferous ironstone from Netley Heath, Surrey; and one antler of Red Deer from the gravel at Banstead Heath (Surrey).

STYRIAN JADE COMPANY, LTD., Messrs. THE.—One bowl and one polished slab of 'Styrian Jade.'

SWAN, Messrs. CHARLES & COMPANY.—Doublet of precious and common opal.

TAYLOR, Miss E. A.—A specimen of *Acanthoceras* aff. *rhotomagense* (Brongniart), from the Cenomanian of Chard, Somerset.

THOMAE, F. A. W., Esq., A.R.S.M.—A series of rock specimens from Mexico.

THRIEPLAND, P. W. MURRAY, Esq.—A slab with examples of *Palaeospondylus gunni* Traquair, from the Middle Old Red Sandstone of Achanarras, Caithness.

TOMKEIEFF, S. I., Esq.—Kaolinite in veins in an ironstone nodule; kaolinite from a septarian nodule.

TRUEMAN, A. E., Esq., D.Sc.—Jet, worked as a cigarette-holder.

TULLY, B. J., Esq., F.G.S.—A series of synthetic sapphires with one spinel, to illustrate variety of colour; several small stones cut as benitoite; a furnace for the preparation of artificial sapphires.

VAUTIN, L., Esq.—Specimens of vanadinite and artificial zincite, from Spain.

WAGNER, Dr. Percy A.—Specimen of platinum-bearing hortonolite-dunite from Onverwacht Mines, Lydenburg district, Transvaal, South Africa.

WALTON, JOHN, Esq., M.A., F.G.S.—Seven microscopic slides of *Mariopteris muricata* (Schlotheim), from the Top Hard Coal of Warsop Main Colliery, Mansfield, Nottinghamshire.

WHELER, A. S., Esq.—Suite of specimens including ruby, sapphire, corundum, topaz, tourmaline, zircon, lapis lazuli and sillimanite, from Mogok Valley, Upper Burma.

WOODWARD, F. R., Esq.—Specimen of auriferous quartz, from Union Reef, near Queque, Southern Rhodesia.

WRIGHT, G. W., Esq.—A specimen of London Clay with lamellibranchs, from Esher, Surrey.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND

1. LONDON AND SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
F. H. EDMUNDS, M.A. } Geologists.

THE survey of the Aldershot map (Sheet 285) was completed by Messrs. Dines and Edmunds. The memoir is approaching completion and it is therefore unnecessary to describe in detail the results of the year's work: there are, however, some features of special interest which deserve mention. The Lower Cretaceous rocks of the area around Godalming exhibit evidences of minor folding and contemporary deposition of sediment. The beds as traced eastwards from Wrecclesham thin out near Guildford, but again thicken south-east of that town. These differences are well shown in the Bargate Beds. Around Easking, Shackleford and Bramley these beds cover wide plateau-like areas, then disappear south of Guildford and reappear near St. Martha, Albury and Burrows Cross: they are absent over wide tracts from Hurt Wood to Wonersh.

The lower division of the Folkestone Beds, the ferruginous loams, shows a similar discontinuity near the former shallows. Mr. Dines notes that these beds expand into a wide area over Hampton Park, Elstead and Peper Harow and overlie the Bargate Beds at Prior's Wood and Northbrook Place. Mr. Edmunds has mapped an area of these beds between Bramley and Northanger, but east of this tract they disappear for over four miles: they reappear at Burrows Cross, where they are exposed in several cuttings for road-widening to a depth of several feet.

Mr. Edmunds records the discovery of *Offaster pillula* (Lamarck) and *Echinocorys scutatus*, var. *depressus* Brydone at Guildford, which prove the occurrence of the Quadratus Zone; the former was first recorded in this district by Prof. Charles Barrois.[1] Neither *Marsupites* nor *Uintacrinus* was found.

Two areas have long been known to be covered with deposits presumably of Pliocene age: i.e., that around Caesar's Camp and Hungry Hill, Aldershot, and the tract north of Netley Heath. The deposits of the latter district contain casts and moulds of shells which are comparable with Red Crag forms (*see* Appendix IX).

The gravels of the rivers draining this country rest on terrace-like features, at several levels above the present flood-plain, but

[1] 'Recherches sur le Terrain Crétacé Supérieur de l'Angleterre et de l'Irlande,' 1876, p. 140.

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the terraces of one river valley differ in relative level from those of other valleys. The subject will receive critical treatment in the forthcoming memoir, and it therefore will suffice here to say that near Farnham the deposits contain locally numerous palaeolithic implements of the 'drift period' types, while recently Major Wade has discovered late 'cave' forms in loam on the lower terrace of the old Blackwater near Farnham. We are indebted to him and also to Mr. Henry Bury for assistance in the field and for the loan of many specimens.

Mr. Edmunds has mapped an interesting deposit on Farley Heath. Gravel to a thickness of ten feet, and consisting of lumps of carstone, is overlain by unbedded buff loam, without stones, and about 5 ft. to 6 ft. thick. There is no gradual passage of the stony to the stoneless deposit but a sudden change. Similar loam was noted on the northern slope of a hill about a mile south of Gomshall, where a thickness of 10 ft. was exposed in an excavation. This loam, that at Farley Heath, and the wind-facetted pebbles[1] in the Godalming district suggest a comparison with the Loëss of the Continent, while the underlying gravel appears to be a coombe deposit. A terrace gravel, perhaps contemporary with the Coombe Deposits, is seen in a pit about a quarter of a mile south of Gomshall. The terrace lies about 30 ft. above the level of the River Tillingbourne and is covered with gravel up to 8 ft. thick in which many large boulders (some measuring 18 in. by 18 in. by 12 in.) of carstone and Lower Greensand chert occur. These beds are contorted, as was noted by R. A. C. Godwin-Austen.[2]

HENRY DEWEY.

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 42.
[2] *Quart. Journ. Geol. Soc.*, vol. vii, 1851, p. 284.

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The Eglwyseg Rocks: An Escarpment of the Carboniferous Limestone.
[Taken from the Geological Survey memoir on 'The Country around Wrexham,' Part I, 1927.]

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2. MIDLANDS DISTRICT

T. C. CANTRILL, B.Sc., District Geologist.

C. B. WEDD, B.A.
R. W. POCOCK, M.Sc.
T. H. WHITEHEAD, M.Sc., A.R.C.Sc. } Senior Geologists.

T. ROBERTSON, B.Sc., PH.D., A.INST.M.M., Geologist.

During the past field season (1926) work has proceeded in the Shrewsbury Sheet (152). Mr. Wedd has resumed his mapping at Westbury, at the western end of the Shrewsbury Coalfield; and in order to include the whole of this coalfield within the area undergoing revision, it has been necessary to survey several six-inch maps on the eastern margin of the Welshpool Sheet (151). Mr. Pocock has continued his survey of the Pre-Cambrian, Cambrian, Silurian, Carboniferous, and Triassic rocks between the Wrekin and the Severn (including the Dryton Coalfield), and also around Upton Magna and south of Shrewsbury. Mr. Whitehead has examined the ground lying south-west of the county town, where Pre-Cambrian and Carboniferous outcrops emerge here and there from beneath the Glacial drift. Dr. Robertson has been engaged upon the Silurian rocks at Much Wenlock, and has also kept under observation an important railway-cutting in process of excavation between Northfield and Barnt Green (L.M. & S. Railway), as it promises to give fresh information as to the succession in the Keuper rocks between Bromsgrove and Birmingham.

Pre-Cambrian.—The mapping of the Uriconian rocks of the Wrekin range is yielding interesting results, but further work is necessary before a satisfactory account of the structure can be formulated.

Cambrian.—Outcrops of the Shineton Shales have now been detected by Mr. Pocock to the west of the Wrekin Fault. The shales are faulted down against the Uriconian rocks along the eastern flank of Charlton Hill, and there is now little doubt that these were the beds entered in the Longwood boring at a depth of 189 ft. below Carboniferous rocks.[1]

Silurian.—Dr. Robertson has been engaged at Much Wenlock, where the Wenlock and Ludlow Series are well exposed. The results of his work on the Upper Ludlow portion of the sequence are embodied in Appendix I. The Lower Ludlow and Wenlock beds have yielded a fair number of graptolites; and the accompanying provisional table (Fig. 5) shows the relationship of the graptolitic fauna to the lithological succession. We are indebted to Dr. G. L. Elles for the

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 46.

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naming of the graptolites and for an indication of the position of each exposure in the graptolitic succession.

Neither the exposures nor the graptolites are, however, sufficiently numerous to permit of much hope that it will be possible to map the graptolitic zones with accuracy. It is therefore of importance to note that an assemblage of forms characteristic of the zone of *Mono-*

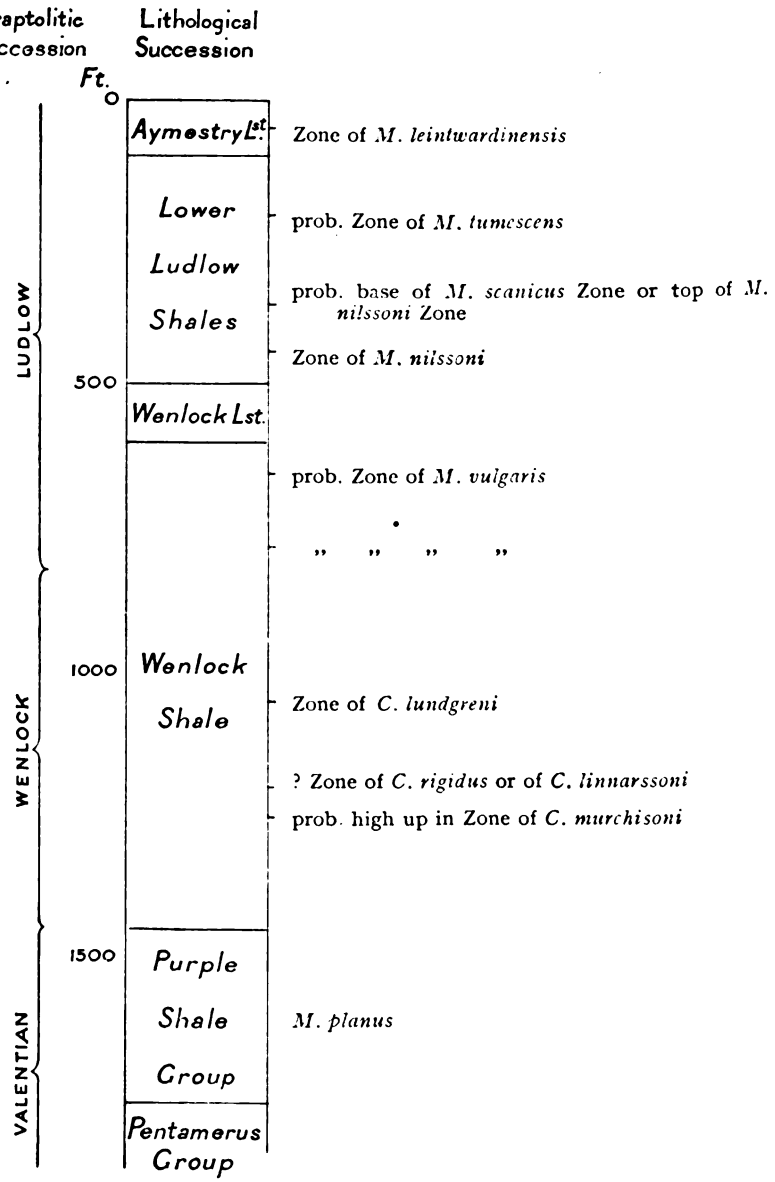

FIG. 5.—*The Lower Ludlow and Wenlock Beds of Wenlock.*

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graptus nilssoni has been found some 60 ft. above the Wenlock Limestone; whilst the abundance of *Gothograptus nassa* in the 200 ft. of shales below the Wenlock Limestone would, other things being equal, be taken as clearly indicative of the zone of *Monograptus vulgaris*. The correspondingly low position of the localities indicating the zone of *Cyrtograptus lundgreni* supports this view. Dr. Elles suggests 'overlap of Lower Wenlock by Middle in this area,' and this would account for the small thickness of beds between the zones of *C. lundgreni* and *C. murchisoni*. No work has yet been done by Dr. Robertson on the zoning of the Valentian beds below; but the record of *M. planus* in the purple shale group[1] fits in with the above account. It appears to be necessary to decide for this district whether the term Wenlock Shales should be used, in the sense of Salter and Aveline,[2] for those beds at Wenlock which come between the Wenlock Limestone and the purple shales of Valentian age; or, in the sense of G. L. Elles and E. M. R. Wood,[3] for those beds 'characterized by graptolites of the *priodon-Flemingii*-type.'

Carboniferous.—In the small inlier of Coal Measures at Dryton and Longwood the higher parts of the measures appear to Mr. Pocock to belong to the Staffordian Series (Halesowen Sandstone and Etruria Marl). Beds of a peculiar 'pellet-rock' occur in the sandstone near Eaton Constantine. The measures that contain the coal-seams formerly worked in this little coalfield are believed to belong to the Yorkian Series; but the tips of the old pits have yielded only *Asterotheca miltoni*, *Neuropteris scheuchzeri*, *Lepidodendron sp.*, *Cordaites sp.*, and *Prestwichia*.

The Coed-yr-allt (Newcastle or Halesowen) Beds, the coal-bearing measures of the Shrewsbury Coalfield, have been traced by Mr. Wedd by the outcrops of sandstones south-eastward from Westbury to Asterley (Sheet 151). Three seams were formerly worked in the lower part of these measures. They lie between two groups of sandstones, of which the upper group makes a more or less continuous escarpment that extends from Broxton Wood, Westbury, to Asterley. The coals are, in upward sequence, (1) the Bottom, Thin, or Best Coal, a good seam 18 in. thick at Westbury, just above the lower sandstone group, which overlies the Ruabon Marl on the west side; (2) the Yard Coal, 60 to 90 ft. higher, about 3 ft. thick, in two or three beds, with partings; (3) the Top or Half-Yard, a fairly good coal, 70 to 100 ft. above the Yard and not far below the higher group of sandstones. The last-named coal was the one most generally worked. Between the Yard and Top Coals a Spirorbis limestone, generally brecciated, is widely distributed.

Of the lower part of the Erbistock or Keele Beds (the Permian of the old maps, 60 N.E. and 61 N.W.), little more has been seen,

[1] Whittard, W. F., *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 381.

[2] 'On the "Caradoc Sandstone" of Shropshire,' *Quart. Journ. Geol. Soc.*, vol. x, 1854, p. 63.

[3] Elles, G. L., 'The Zonal Classification of the Wenlock Shales of the Welsh Borderland,' *Quart. Journ. Geol. Soc.*, vol. lvi, 1900, p. 371.

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except at Stoney Stretton, where Mr. Wedd finds that somewhat calcareous purple sandstones have been quarried. In the top of the Erbistock Beds, of which it constitutes roughly a quarter of the whole thickness, the Alberbury Breccia crops out with a symmetrical basal curve from a southward strike on the west side of Loton Park, Alberbury, to an eastward one at Cardeston. Its shallow synclinal curve is superimposed across the north-eastward continuation of the Long Mountain Syncline, itself almost equally uniform but much more steeply folded. Above the Alberbury Breccia the base of the Bunter comes on with a curve less regular and less in degree, so that it appears to overstep the higher beds of the Breccia north-westward and south-eastward. The whole indicates a uniform synclinal folding, mostly effected before the deposition of the Upper Coal Measures, but in less degree renewed at intervals beyond Bunter time.

The Alberbury Breccia group, consisting chiefly of highly calcareous purple sandstone full of limestone-fragments derived from the local Carboniferous Limestone, as well as other debris, extends between Alberbury and Cardeston up to the base of the Trias without the intervention of any other type of 'Permian.' In the Deer Park at Alberbury the several beds of breccia, separated by softer partings, rise in tiers of escarpments, which are divided into three groups by two bands of softer beds, eroded into valleys but not themselves exposed. The lowest bed of the breccia group along the south-west side of the deer-park caps an escarpment of brown sandstone, which, like other sandstones in the middle part of the Erbistock Beds, contains numerous quartz pebbles but no limestone-fragments. Below the base of this group, with the exception of a 2-ft. bed a considerable distance down, no similar breccia has been found.

Mr. Whitehead finds that beds of typical Keele facies are seen near Hookagate Station (Shropshire and Montgomeryshire Railway), so that the line of junction between these and the underlying grey group (Coed-yr-allt, Newcastle, or Halesowen Group) evidently runs between the station and Pulley Common.

Trias.—Mr. Wedd finds that above the Erbistock Beds the softer Bunter sandstone comes on with a different type of surface-configuration, generally with a depression at the junction. Beyond this the red sandstones of the lower Bunter not far above its base rise into rounded hills before sinking into the Severn valley, within which they reappear locally in low banks rising through the boulder-clay. These lower sandstones seem to be free from pebbles except near their base. But at Cardeston Rectory a southward-trending fault of eastward downthrow brings in pebbly cross-bedded red sandstone of Pebble Bed type.

In Mr. Pocock's ground the Lower Mottled Sandstone rests against the western flank of the Wrekin, and between the Forest Glen and Little Hill there is no evidence to support the view that it is here faulted down against the Uriconian rocks. Evidence to the

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contrary is afforded by what is believed to be a contemporaneous basal breccia of the Trias, made up largely of angular Uriconian fragments with some blocks of the Cambrian quartzite, exposed in a pit near the rifle-range.

Superficial.—Except in the Severn valley south of the river, and on its southern brow, where the Bunter and the Alberbury Breccia make relatively high ground, as also where the Coed-yr-allt sandstones rise in escarpments between Westbury and Asterley, the greater part of the surface between Hanwood, Alberbury, and the Long Mountain has been found by Mr. Wedd to be covered with drift of varying thickness, for the most part a stony grey clay. But much clayey gravel flanks the valley of the Westbury brook from Stoney Stretton eastward, where similar but later gravel makes terraces on the south side. Moreover, westward from Onslow Hall, north of which a recent boring has proved 111 ft. of drift, quartz sand, locally red and of Triassic origin, as well as clayey gravel, rises in numerous hillocks.

The boulder-clay of the area south-west of Shrewsbury, surveyed by Mr. Whitehead, seems to be of two types: (1) a brown clay with stones derived mainly from Wales or the Welsh border region; (2) a red or reddish clay with stones and boulders of northern origin.

The sands and gravels of the Rea valley, and of a tributary that joins it at Hookagate, appear to form a series of terraces, of which three may be clearly discerned. The lowest, about 10 ft. above the present flood-plain, is evidently purely a river-terrace. The second, on the average about 20 ft. above the flood-plain, is well developed at Meole Brace and probably occurs also at Hanwood Bank. The gravels of which it is composed are perhaps of late fluvio-glacial origin. The third terrace lies about 60 or 70 ft. above the flood-plain, but is much less regular than the others. The gravel of which it is composed is very coarse, with many angular or sub-angular fragments and a clayey matrix. There is evidence that this highest gravel is older than the brown 'Welsh' boulder-clay of the district, and may be intermediate in age between this and the red clay with northern erratics.

T. C. CANTRILL.

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3. YORKSHIRE DISTRICT

Headquarters : York

C. E. N. BROMEHEAD, B.A., District Geologist.
G. V. WILSON, B.Sc.
D. A. WRAY, M.Sc. } Senior Geologists.
J. V. STEPHENS, B.Sc., B.ENG.
WILFRID EDWARDS, M.A. } Geologists.

The resurvey of the Glossop Sheet (86), of which a small part was undertaken by Mr. Wilson in 1925,[1] has occupied the whole staff during the field-season. The grits and sandstones of the Millstone Grits have been mapped in much greater detail than was attempted during the original survey and, partly as a consequence of this work, the positions of many additional faults have been laid down. The marine bands have been traced, prolific exposures of those characterised by the α, β, and γ mutations of *Reticuloceras reticulatum* Bisat being found. It is doubtful whether more than one β bed occurs, but one exposure is notable ; in Heyden Clough, about half a mile south of the old quarries, shales containing *Reticuloceras reticulatum*, mut. β, *Homoceras proteum* Brown, *Pterinopecten*, *Orthoceras* etc. are seen for some 100 yards ; they include a layer of large calcareous bullions which yield numerous uncrushed goniatites ; the shells are well preserved and contain a greenish yellow petroleum in their hollow interiors. The marine bands with *Gastrioceras cancellatum* and *G. cumbriense* have also been traced. It is noticeable that the cycle of deposits is normally a coarse grit, with or without a fireclay and coal on its surface, followed almost immediately by a marine band consisting of clay shales ; these pass gradually upwards through sandy shales, mudstone and rag, flagstones and sandstones to a coarse grit again. It is clear, therefore, that the downward movement of the basin of deposition took place in a series of small jerks, between which sedimentation gradually overtook subsidence.

Mr. Wilson notes that the peculiar fireclay at the top of the Rough Rock is of a semi-bauxitic character indicative of prolonged exposure at the surface. The lower beds of the Kinderscout Series, exposed in the Cheshire and Derbyshire parts of the area, have been studied by Messrs. Stephens and Edwards, while Mr. Wray has worked mainly on the Coal Measures in the north-eastern part of the Sheet ; an interesting problem is discussed by him in Appendix VI (p. 127). Mr. Stephens has mapped some of the Coal Measures of the Lancashire and Cheshire basin, concerning which the old maps gave

[1] ' Summary of Progress ' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 58, 59.

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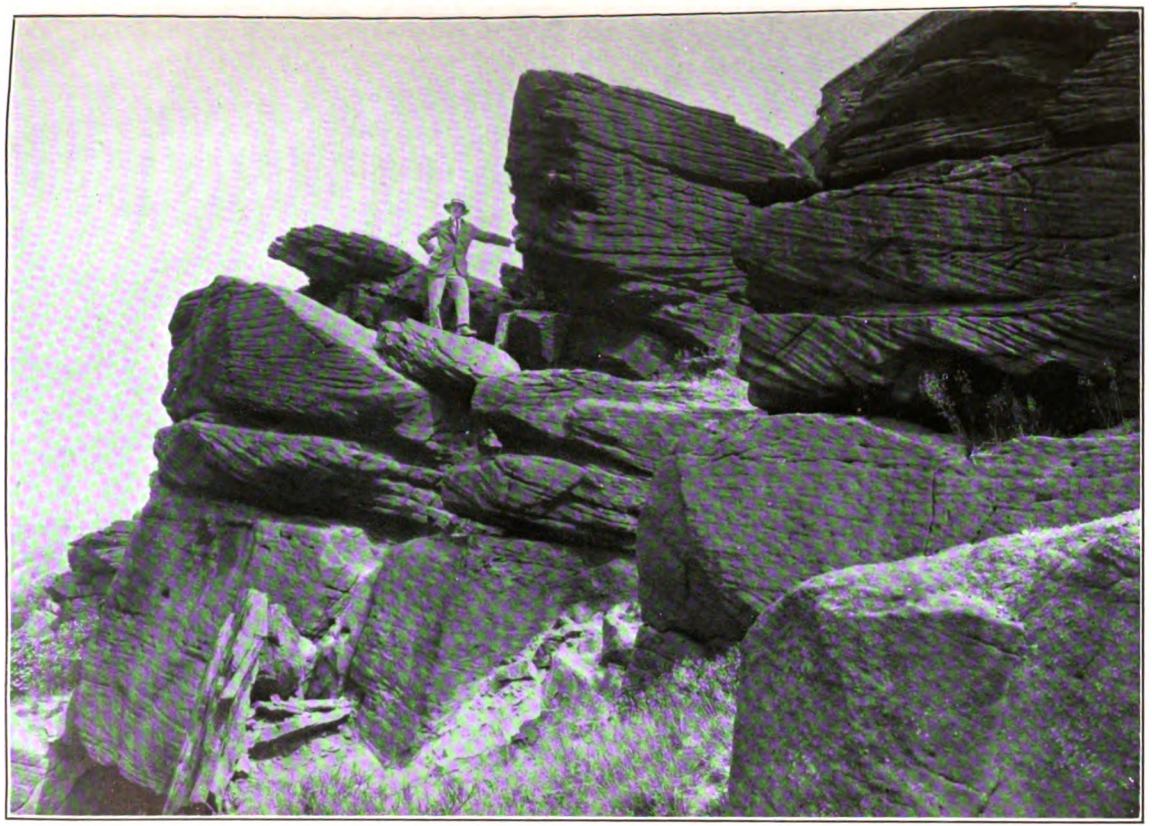

Rough Rock, Scar Wood, Halifax.

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only meagre information; he and Mr. Edwards have studied the glacial phenomena near the margin of the Lancashire ice. Mr. Wilson has continued his general supervision of the Concealed Coalfield of Yorkshire and Nottinghamshire and deals with certain new developments in Appendix VII (p. 138).

In addition to routine field-work Mr. Stephens has done much work on the Water Supply of Derbyshire, and Mr. Wilson was working for three months in the Scottish Highlands.

C. N. BROMEHEAD.

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4. LANCASHIRE DISTRICT

Headquarters : Manchester

W. B. WRIGHT, M.I.M.E., District Geologist.
R. L. SHERLOCK, D.Sc., A.R.C.Sc., Senior Geologist.
W. LLOYD, B.Sc.
L. H. TONKS, M.Sc. } Geologists.
R. C. B. JONES, M.C., M.Sc.

In Lancashire the revision of the Manchester area, Sheet 85, has been continued. The surface survey is now completed, but there is still some mining information outstanding. Much assistance has been given by the mining companies, and the boring firms operating in the district have also given free access to their records

The ground surveyed by Mr. Lloyd embraces the town and northern outskirts of Oldham, and the districts of Royton and Shaw, extending eastwards to the Tame Valley north of Delph. Mapping of Millstone Grit and Lower and Middle Coal Measures has been continued.

No beds comparable with the Haslingden Flags in lithological character or quality have been observed in this area in the higher part of the Millstone Grit Series. Where, therefore, typical coarse Rough Rock is seen to rest on flagstones of a rougher type, the latter have been separated as Rough Rock Flags. This procedure conforms with that already adopted in Yorkshire.

The outcrop of Lower Coal Measures north-east of Oldham has presented many difficulties and intricacies on account of the irregular variation in the sandstone subdivisions; and the difficulties of detailed mapping and correlation have been accentuated by the dearth of reliable shaft and bore sections. There is, however, evidence for supposing that the main sandstones[1] between the Lower Mountain and Arley (Royley) Mines die out altogether or dwindle to trifling proportions as they pass westwards under the cover of Middle Coal Measures. A considerable area of unworked Lower Mountain Mine lies to the west of Shaw at workable depths, and there seems no reason to anticipate any depreciation in the quality of the coal. The Upper Mountain Mine is either absent or of inferior quality and thickness over all the district.

The Middle Coal Measures are largely concealed under Glacial deposits which in places reach a thickness of 150 ft. Many additional detailed shaft sections of Middle Coal Measures have been obtained, however, and the succession, with its variations, is well established.

Modifications of former mapping have been effected in the area north and west of Royton on the evidence of borings, the chief

[1] 'Summary of Progress' for 1922 (*Mem. Geol. Surv.*), 1923, p. 47.

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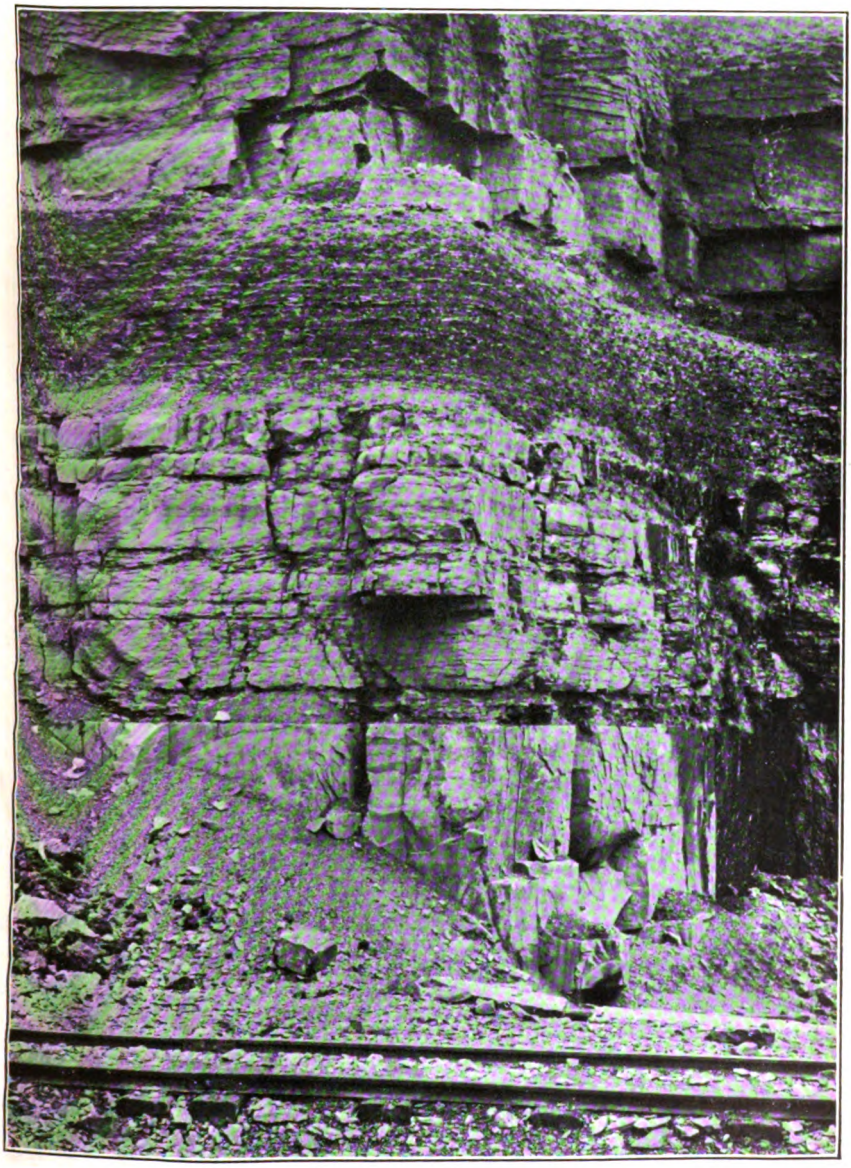

Rough Rock and Haslingden Flags, near Edenfield.
[Taken from the Geological Survey memoir on 'The Geology of the Rossendale Anticline,' 1927.]

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importance of which is the proved existence of additional areas of Middle Coal Measures.

In the area north of Manchester, where Mr. Tonks has been working, the Coal Measures of the western part of the Oldham coalfield, at Middleton and Moston, are proved by extensive mining and boring operations; and although the faulting is somewhat complicated, the construction of the six-inch maps presents comparatively little difficulty. Westwards, however, between Unsworth and Middleton, and north of the proved crop of the Permo-Triassic rocks around Blackley and Heaton Park, over an area of about six square miles there are no exposures, owing to the great thickness of the drift, no borehole records have been obtained, neither have any mining operations been carried out. On the western side of this area the succession in the Coal Measures around Radcliffe is well known, and it can be extended eastward for a little distance towards the unknown area by means of isolated boring records. Although it is possible to correlate broadly the succession in the Oldham coalfield with that about Radcliffe, the interval is too great in this series of variable beds to permit of any detailed correlation; and hence it is impossible to join up by projection across the unexplored ground. Moreover, even if this were possible, there is a complete lack of evidence as to the extent or nature of the faulting. In so far as it would obviously be impossible to imagine the complexity of the faulting in some of the proved areas of this coalfield if it were unknown, it follows that any attempt to forecast an outline of the probable structure of this area could have little chance of success. A diagrammatic outline has, of necessity, been attempted on the one-inch map (Manchester, Sheet 85) at present in course of completion, but no certainty is felt in the interpretation reached.

It is interesting to consider the reasons for the unproven character of this area. It may be that the great thickness of drift and the consequent absence of recognisable outcrops have prevented the gradual development of the area along with the rest of the coalfield. A contributory cause may be the fact that the Arley Mine, which has been worked to a small extent at Bury, proved to be of very inferior quality. This usually valuable coal was therefore never followed to the deep, and no shafts were sunk to it which might prove the nature and extent of the upper measures.

Whatever causes may have combined to produce the present state of affairs it must be pointed out that on the west side the Trencherbone and associated coals are last known striking directly into this unknown area, and on the east the Black and its associated seams also strike towards it. The evidence at present available suggests that coals exist untouched at no great distance below the base of the drift, and this evidence certainly seems strong enough to warrant the exploration of the area by borings. It is regrettable that the only attempt at exploration which has been made so far[1]

[1] Dickenson, J., 'Heaton Park Borehole, near Manchester, with notes on the surrounding,' *Trans. Manch. Geol. Soc.*, vol. xxviii, 1902–04, pp. 69–86.

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was situated too far south, as the sequel proved, to afford any criterion of the nature of the bulk of the ground in the area under discussion.

During 1926 the area south of the River Irwell, including Clifton, Pendlebury, and Swinton, was surveyed by Dr. Sherlock. The Coal Measures are only exposed in the bottoms of a few valleys, and in mapping the geologist is almost entirely dependent on the information obtained from the collieries. We are particularly indebted to Mr. P. L. Wood, General Manager of the Clifton and Kersley Collieries; Mr. J. T. Browne, F.G.S., General Manager of Messrs. Andrew Knowles & Sons, Ltd.; and Mr. Jesse Wallwork, Managing Director of the Bridgewater Collieries, Ltd.

Coal has been worked as far south as Patricroft and Salford, say about a quarter of a mile north of the L.M. & S. Railway, Manchester to Liverpool. The dip of the strata carries the coal seams to a considerable depth near this southern limit. The chief seams in the area are the Rams, Crumbourke, and Worsley Four Feet. The last of these has hitherto been taken as the top of the Middle Coal Measures, but it is probable that the boundary will have to be taken at a considerably higher horizon.

The Bunter is exposed in cuttings on the L.M. & S. Railway at Eccles and Monton, and along the Manchester Ship Canal, at Eccles, there are large excavations in this formation. The rock is a red sandstone, often with greenish-yellow patches and is of Lower Mottled Sandstone type. However, lenticles of pebble-beds occur in the rock and it is evident that it is impossible to divide the Bunter into Lower Mottled Sandstone and Pebble Beds.

Near the River Irwell, Glacial Drift is in places very thick. Thus, the L.M. & S. railway-cutting at Pepper Hill, near Clifton Junction, though 118 ft. deep, is entirely in Drift. The Irwell terraces are bordered here by prominent Drift bluffs.

The resurvey of the country to the south of Bolton has been continued by Mr. Jones. This ground is occupied by the productive Middle Coal Measures, overlain to the south by the Permo-Trias. The whole area is covered by drift so that exposures are rare and are confined to a few stream sections and to the outcrops of the larger sandstones, which form ridges often clear of boulder-clay.

Coal has been worked throughout the ground covered by the Middle Coal Measures, and to the south mining has been continued beneath the Permo-Trias. Owing to the great amount of mining information the map can be made with considerable accuracy despite the lack of exposures. For this information we are indebted to Hulton Colliery Co., Ltd., Mr. J. Livesay of Rosehill Colliery, and Mr. F. Carter of the Earl of Bradford Estate Offices, Bolton.

W. B. WRIGHT

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5. CUMBERLAND DISTRICT

Headquarters : Whitehaven

BERNARD SMITH, M.A., Sc.D., District Geologist.
E. E. L. DIXON, A.R.C.Sc., B.Sc.
T. EASTWOOD, A.R.C.Sc. } Senior Geologists.
F. M. TROTTER, M.Sc.
S. E. HOLLINGWORTH, M.A., B.Sc. } Geologists.

The mapping of Sheets 28 (Whitehaven) and 22 (Maryport) has now been completed, whilst only 12 sq. miles remain to be surveyed in Sheet 18 (Brampton). Several new road cuttings in the district have been examined and visits paid to the sites of the Waterworks schemes at Bordale Hause, Patterdale (Penrith Waterworks) and Haweswater (Manchester Waterworks). The depression in coal and iron mining materially reduced the number of new boreholes and sinkings to be visited, but a great number of records of old shafts and bores have been collected, and mine plans examined, for the preparation of six-inch maps.

BRAMPTON SHEET

Amongst the Carboniferous rocks of the northern part of the Brampton Sheet (18) and the southern part of the Bewcastle Sheet (12) the Cementstones, Fell Sandstone and the lower part of the Seminula Zone (probably S_1) have been identified by Mr. Trotter. Strata in the Cementstone Group are exposed near Kirkcambeck and Rinnion Hills. They yield the fauna of the *Athyris glabistria* Zone of Garwood, several characteristic forms having been determined by Mr. J. Pringle. The overlying Fell Sandstone Group is poorly exposed, but includes thin earthy limestones as well as thick sandstones.

Three thin marine limestones lie at or near the base of the Seminula Zone (S_1) and their recognition along an outcrop of three miles in and near the Kingwater, north-westwards from Desoglin, supplies the key to the interpretation of a large drift-covered area. Higher beds in the Group (S_2?) have been found in the River Irthing north of Gilsland. All the above-mentioned shallow-water strata are more marine in character than their representatives in Northumberland, thus demonstrating the existence of land to the north-east of our area and more open sea to the west and south-west.

The Thirlwell Coal crops out north of War Carr and has been mapped for a considerable distance.

In the overlying Lower Limestone Group Mr. Trotter has identified

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the Naworth Limestone[1] at several localities, which makes it possible to map the base of the Lower Dibunophyllum Zone (D_1) throughout the Brampton Sheet. The Denton Mill and overlying limestones in the group are well exposed in the River Tipalt near Greengate Well and yield a characteristic D_1 fauna.

In the River Tipalt also there is exposed, between Greengate Well and Thirlwell Castle, a continuous section in the Middle Limestone Group from the base of D_2 to the Scar Limestone. In this neighbourhood the following limestones are underlain by thin coals: Single Post, Cockle Shell, Scar and Five Yard. Immediately to the south borings have proved thin coals below the Three Yard and Four Fathom limestones.

Mr. Hollingworth, working in the South Tyne area, finds that the beds from below the Scar to the Great Limestone are well exposed along the river and its south-western tributaries. They correspond closely with their equivalents in the Alston Moor mining area.

In the Upper Limestone Group the Little Limestone and its associated coals have been traced by Mr. Trotter from near Greenhead eastward to the edge of the Sheet. The lower coal is worked at the South Tyne and Plainmeller Collieries.

In the valley of the South Tyne Mr. Hollingworth found good exposures of the beds between the Great Limestone and the Firestone Sill at several points north of Slaggyford. To the west of the South Tyne sections above the Firestone Sill are poor, particularly over the high peat-covered ground west of the Faugh Cleugh (N.W.—S.E.) Fault and its southerly continuation to the head of the Knar Burn. East of the Tyne, however, excellent sections of some 600 ft. of strata above the Great Limestone are exposed in Snope Burn. The succession here closely parallels that established by Mr. Trotter in the ground to the north, the most interesting result being the recognition of a series of brachiopod-bearing horizons which can be traced for many miles in both areas (Appendix II, pp. 98–107). Throughout the South Tyne area the Little Limestone coal appears as two seams separated by a few feet of shale and mudstone. The higher, which is anthracitic in character, is now being worked from outcrop at Barhaugh and Snope Burn.

In the area examined by Mr. Hollingworth a whin sill crops out in Gilderdale Burn below the Scar Limestone and is probably continuous with that at the same horizon in Croglin Water.[2]

In Faugh Cleugh whin underlies the Little Limestone for half a mile east of the Faugh Cleugh Fault and probably destroys the underlying Little Limestone Coal. No whin was encountered in a boring to the Great Limestone immediately west of the fault, hence it is probable that the intrusion rose along the fault-plane.

Mr. Trotter has traced a whin dyke from Denton Fell to Wydon, trending approximately E.15°N. The old interpretation that it is

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix II, Fig. 16, p. 158.

[2] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 83.

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intruded along a large fault, which repeats the outcrop of the 'Millstone Grit' to the north, must be discarded, as the Little Limestone Coal has been found at the same horizon on both sides of the dyke at two points underground and there is no sign of a break on the line of the dyke in the South Tyne near Wydon.

The outcrop of the 'Whin Sill,' crowned by the Roman Wall, forms a bold crag 100 ft. in height near Carvoran and extends eastwards to Cockmount Hill (Sheet 19) where it disappears beneath drift.

Mr. Hollingworth finds that Carboniferous drift occupies much of the low ground along the South Tyne, whilst its tributaries from the south-west contain New Red drift from the western side of the watershed (Vale of Eden) mixed with local material. The ice which carried the drift was probably confluent with local ice in the South Tyne valley.

Maryport Sheet

The field-work in Sheet 22 (Maryport) has been completed by Mr. Eastwood. The Maryport Fault, crossing the area obliquely, brings New Red rocks on the north-west against the coalfield, which is underlain by the Carboniferous Limestone Series in the south-eastern portion of the area. These are in turn underlain by a series of basaltic lavas and the Skiddaw Slates, which, though poorly represented in Sheet 22, fall into portions of six-inch maps that overlap into the one-inch Sheets 23 (Cockermouth), 28 (Whitehaven) and 29 (Keswick).

The Skiddaw Slates call for little comment, beyond the fact that the Watch Hill Grit, some little distance below their summit, is present in the Cocker and its tributary close to the railway at Cockermouth, and also, farther to the south-west, at Harrot Hill. At both sites it was noted by Ward and Goodchild. A representative of the highest sandstone—similar to that of Latterbarrow—has been discovered in a gill near Redmain.

The junction of the Skiddaw Slates and the volcanic series near Cockermouth is marked by a conglomerate which indicates a period of erosion. This conglomerate preceded the lavas which have hitherto been regarded as part of the Borrowdale Series. The lavas, however, present features which suggest that they may belong to a younger suite. Further investigation is needed before this question can be settled. They are dark blue compact basaltic-looking and olivine-bearing rocks which, though frequently amygdaloidal, show little or no signs in the field of scoriaceous or flow structures. The conglomerate contains pebbles of the Latterbarrow Sandstone and of other rocks such as rhyolite or flinty rhyolitic ashes. In this connexion it is pertinent to recall the lumps of rhyolite[1] or rhyolitic

[1] Green, J. F. N., 'The Age of the Chief Intrusions of the Lake District,' *Proc. Geol. Assoc.*, vol. xxviii, Pt. 1, 1917, p. 9. Mr. Green suggests that the Skiddaw Slates were suffering some erosion during the formation of the Latterbarrow Sandstone.

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ash that occur, together with fragments of Latterbarrow Sandstone and other rocks, in a conglomeratic breccia (or agglomerate) at Capel Crag, which forms part of the Mottled Tuffs overlying the Latterbarrow Sandstone in the area surveyed by Mr. Hollingworth near the River Calder, east of Egremont.

In the Limestone Series the divisions adopted in the Whitehaven Sheet are recognisable, although to the north there is a greater development of shale in and above the Fourth Limestone.

The Seventh Limestone occurs south-east of Bridekirk, and was formerly quarried at East House about ¾ m. E. of Brigham. A new exposure has been found in the Derwent 600 yds. east of Papcastle Station. The Fourth Limestone is exposed at various places between Tallentire, Bridekirk and Broughtoncraggs west of Papcastle Station. At the last locality quarries give excellent sections from the Fourth Limestone to the Hensingham Grit. Beds from the Orebank Sandstone to the First Limestone are also well exposed around Tallentire Hill and at Hotchberry Brow south of Brigham. In both cases the new maps show considerable alterations.

In the Hensingham Group shales and sandstones above the basal grit have been located south-west and north-west of Dovenby, between Gilcrux and Ward Hall, and at Rosegill near Bullgill.

Owing to the absence of recognisable horizons it may be necessary to omit Millstone Grit from most of the Maryport Sheet.

The Coal Measures of most of that Sheet have been described in previous Summaries, but it is interesting to note that north-west of the River Ellen, between Maryport and Bullgill, the measures rise steeply towards the Maryport Fault. At Oughterside workings have not reached the immediate vicinity of the fault, but a curiously sharp monoclinal fold, ranging east and west and pitching east, has been encountered between the Oughterside shafts and the main Carlisle road farther north.

BERNARD SMITH.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters : Newcastle-on-Tyne

R. G. CARRUTHERS, District Geologist.

G. A. BURNETT, B.Sc.
J. MADEN, M.Sc.
A. FOWLER, M.A., B.Sc.
W. ANDERSON, M.Sc.
} Geologists.

In Northumberland work was continued on the Cheviot lavas and granite, of Old Red Sandstone age, and in Carboniferous rocks ranging from the Limestone Group up to Lower Coal Measures. Mr. Burnett was engaged in one-inch Sheet 5, revising the high ground towards the centre of the Cheviot massif. Mr. Fowler's work lay for the most part in Coal Measures north and east of Morpeth, while Mr. Maden dealt with the Limestone areas west of the town, being joined by Mr. Anderson after the conclusion of his Scottish work. As a result of this work round Morpeth the revision of one-inch Sheets 9 and 10 was finished before the end of the season. Mr. Carruthers revised small areas of Lower Carboniferous rocks on either side of the Tyne valley (Sheet 20).

Cheviot Lavas and Granite.—The augite-granite boss of the Cheviot massif is, as was recognised long ago by Teall,[1] predominantly a red rock, with subordinate areas of grey granite, less rich in augite, on Standrop Rig. The margin is difficult to trace, both to the east and north, for it is much obscured by hill-peat, while the stream sections often coincide with crushes and shatter-belts carrying vein-quartz. So far as can be seen, the boundary is most irregular, the granite fingering off into the lavas in a succession of small sill-like intrusions. In addition, there seems to be, at times, definite absorption of the neighbouring andesites, the two rocks shading into one another imperceptibly. Alterations in the mapping have been occasioned by the recognition of these facts, and also by evidence that the outstanding masses of lava south-west and south of Langlee Crags are ' stoped xenoliths ' entirely surrounded by granite : on the published map they are shown as part of the main lava outcrop.

Lower and Middle Limestone Groups.—Whilst revising ground north of Kirkwhelpington, on either side of the Otterburn-Newcastle main road, Mr. Anderson's identifications of some of the limestones proved to be of much interest. Both the Watchlaw and the Woodend Limestones were noted ¾ mile north of Rochester, their characteristic pale creamy-grey colour and pseudo-brecciated structure agreeing perfectly with the nearest known exposures at Alnwick,

[1] *Geol. Mag.*, Dec. III, vol. ii, 1884, p. 106.

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20 miles away. Again, ¾ mile north-east of Rochester, the Oxford Limestone was found with its *Girvanella* nodules in abundance, and was subsequently identified at other points in the district. Most of the higher limestones had been correctly identified previously. It was noted that from Hartington southwards the Great Limestone loses the pale pinkish tinge and coarse texture peculiar to this horizon in all the northern exposures: it becomes dark and close-grained, and in fact much like other members of the series.

Upper Limestone Group.—In addition to the limestones already mapped in this Group, Mr. Maden has discovered three others, hitherto unrecorded, between the tower in Dixon's Wood and Witton Shield, east of Netherwitton. They are exposed in a stream running through the wood, the thickest showing 30 ft. of limestone and shale interbanded: the other two beds are each about 4 ft. thick. It will not be possible to correlate these limestones until adjacent areas are surveyed, and indeed the mapping on either side of the Font valley below Netherwitton presents many difficulties owing to the very low angles of dip and the relative scarcity of exposures. The Group contains several thin coal seams, some of which have been wrought to a fair extent in past times. During the coal strike, workings in a well-known seam of soft, rather dirty coal, above the Stanton Limestone, were re-opened near Stanton House. East of this Mr. Fowler found refuse heaps from a higher seam, not shown on the published map: fragments of parrot coal on these heaps agree in character with those from the higher of the two seams mapped on either side of the Font east of Nunriding Hall.

Coal Measures.—Around Morpeth several coals near the base of this series are mapped, but their correlation is as yet unsettled. Mr. Fowler reports that the lowest now wrought, called the Victoria Coal, lies 12 fathoms below the Bessie Grey or Brockwell Coal, but until the intervening ground has been examined it is impossible to say whether or no these agree with the Victoria and Brockwell Coals of the Tyne valley.

There are good cliff sections in the ravine of the Wansbeck below Morpeth, and below Bothal two *Carbonicola* and *Spirorbis* bands are seen, probably representing those known in the Ashington district 5 or 6 fathoms above the High Main Coal. Towards the mouth of the river large faults are known, trending west by south: one of these, called the Stakeford Dyke, has a throw of 80 to 90 fathoms down north and divides south of the river into a westerly branch (60 fathoms), and another 28 fathoms down north-west. North of Morpeth, on Pegswood Moor, a fault of some size (30 fathoms down north-east) and hitherto unrecorded, has been proved in working the lower coals from Morpeth Moor Colliery.

The 'wash-out' in the Woodhorn Low Main Coal near Woodhorn Demesne is probably connected with that in the undersea workings of Camboise Colliery, 1 mile east of Horsebridge Head, and known also in the Low Main of the Blyth district to the south. There may

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be a continuation northwards beyond Woodhorn: at any rate the Low Main seam is either absent or is abnormally thin at Ellington Colliery, 2 miles north of Woodhorn.

Glacial.—In the Cheviots Mr. Burnett reports that the dry valleys, trending east or south-east, which are so prominent near Wooler, continue well within the hills. The highest so far noted is at the head of New Burn (1,450 ft.), a stream running into Harthope Burn from the north, about ⅓ mile below Langleeford.

West of Morpeth, in the Hartburn valley, the boulder-clay is 30 ft. thick or more towards Scots Gap Station. Farther east, near Mitford Church, the sands and gravels intercalated between the two clays become prominent, fully 25 ft. being seen there high up the river bank. Certain belts are concreted into a firm mass, and stand out prominently from the gravel scar. Similar 'bound gravels' are seen on the coast beneath the sandhills near Lyne Skears: in both cases they rest on the lower boulder-clay.

Striated surfaces are not common, though markings pointing due east have been noted on the East Whitehill dolerite sill, north of Kirkwhelpington. Stretches of flat alluvial ground, apparently representing the sites of temporary late-Glacial lakes, have been observed ½ mile west of Hartburn village and again ⅝ mile north of Cambo. The extensive flat, hitherto mapped as a high river-terrace, on the north side of the Font at Netherwitton, may have a similar origin.

R. G. CARRUTHERS.

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(B)—SCOTLAND

1. AYRSHIRE

E. B. Bailey, M.C., B.A., District Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc.
A. G. MacGregor, M.C., B.Sc. } Geologists.

The revision of the post-Silurian geology of Sheet 14 has been concluded in the areas lying north-west and south-east of the Carboniferous Limestone basin of Dailly. Messrs. Eyles and Simpson have worked in both these areas, and Mr. MacGregor in the more south-easterly.

Lower Old Red Sandstone.—This division has two distinct outcrops, the one centring about Maybole, the other running south-west from Dalleagles by Dalmellington and Straiton. In each of these areas a sedimentary group below is succeeded by a volcanic group. Conglomerates are known at or near the base of the sedimentary group and recur both immediately below and intercalated with the lower lavas of the volcanic sequence. Up to a certain level all these conglomerates consist mainly of pebbles of pre-Devonian greywacke and chert.

A conglomerate that has been traced among the lower lavas of the south-western district, at a slightly higher level than those just considered, is noteworthy for its contained pebbles of felsitic quartz-porphyrite.

In the Maybole area the Lower Old Red Sandstone lies at gentle angles and is comparatively little faulted. In the Straiton belt, which flanks the main Southern Upland Fault, there is much faulting and folding. As a result, steep dips are a common feature of a strip of country four miles in width. Mr. MacGregor finds that the main faults, anticlines and synclines run south-west, but are combined with numerous transverse faults and lines of steep pitch that introduce much confusion in detail. This steep belt includes outcrops of previously folded Silurian and Ordovician rocks.

Upper Old Red Sandstone.—The lower Old Red Sandstone is largely absent from the Dailly district owing to erosion before the Upper Old Red Sandstone was deposited. Mr. Eyles has examined exposures of Upper Old Red Sandstone lying on Ordovician in Shiel Burn, two and a half miles south of Crosshill. The base of the Upper Old Red Sandstone consists at this point of sandstone, while a little higher up a quarried cornstone is met with. Two miles farther south-east, beyond Glenalla Fell, Sheet 8 shows two small outliers of Upper Old Red Sandstone resting upon Lower Old Red Sandstone lavas. The larger of these has been confirmed by Mr.

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MacGregor. It contains worked cornstone and has a basal conglomerate with pebbles of red porphyrite.

Interbedding of Upper Old Red Sandstone and Calciferous Sandstone types of sediment has been noted in previous 'Summaries of Progress.' Mr. Eyles has now found grey marly and sandy shales of a kind characteristic of the Cementstone Group of the Calciferous Sandstone outcropping in a tributary of Toddy Burn, only a short distance above worked cornstones three miles south-south-west of Crosshill. These shales contain remains of plants and fish, as yet undetermined. It is probable there is only a small thickness of Upper Old Red Sandstone in this district.

Glacial.—In the neighbourhood of Straiton there are distinguishable lower and upper drifts. The lower drift is a typical boulder-clay and contains *small* boulders of Loch Doon granite. The upper drift is much more friable and contains *large* boulders of Loch Doon granite. Mr. MacGregor is of opinion that the upper drift was deposited during the melting of the ice.

Near Maybole there are three kinds of drift (1) boulder-clay (2) angular sandstone drift, (3) sand and gravel. The two latter have hummocky forms which in the case of (3) include a well marked esker-ridge. The angular sandstone drift is a confused assemblage of the local Old Red Sandstone which cannot in some exposures be distinguished from sandstone disintegrated *in situ*. On the other hand it generally contains a few transported pebbles and occasionally it can be shown to overlie boulder-clay. The angular sandstone is sometimes mixed with sand derived from true Glacial sand. Probably the Maybole sands, gravels, and angular sandstone drift represent a complicated marginal phase of glaciation where thawing and freezing, retreat and advance alternated with one another. A similar interpretation has recently been put forward by Prof. Charlesworth.[1]

E. B. BAILEY.

[1] Charlesworth, J. K., 'The Readvance, Marginal Kame-moraine of the South of Scotland, and some Later Stages of Retreat,' *Trans. Roy. Soc. Edin.*, vol. lv, 1926, p. 39.

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2. LANARKSHIRE AND PEEBLESSHIRE

J. E. Richey, M.C., B.A., District Geologist.

H. H. Read, D.Sc., A.R.C.Sc., Senior Geologist.

G. Ross, B.Sc.
J. Phemister, M.A., B.Sc. } Geologists.

Little new field work has been carried out in these areas during the past year. The revision of one-inch Sheet 24 (Peebles) has been continued by Dr. Read. The Lower Old Red Sandstone rocks, of which a detailed account was given in last year's 'Summary of Progress,' have now been re-mapped as far north as West Linton. The investigation of the Calciferous Sandstone volcanic rocks in Sheet 24 and along the eastern margin of Sheet 23 has been almost completed by Mr. Phemister. Among the lavas to the east of Carnwath he has found interesting varieties of tholeiitic and doleritic character.

Mr. Ross has investigated in the field superficial deposits near Lanark (one-inch Sheet 23), details of which are given in Appendix X, p. 158.

J. E. Richey.

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3. FIFE AND KINROSS

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} Geologists.

Up to the present time the surface geology of about two-thirds of the Carboniferous area in one-inch Sheet 40 has been revised The structure of the country, however, even where not concealed by a thick mantle of drift, is so excessively complicated by folding, faulting, and intrusion of dolerite sills that surface indications play only a minor part in the construction of a map which is to be of service to the mining community. The greater the complexity, the more numerous the bores put down with a view to its unravelling, each of which has to be considered and reconciled with its neighbours before outcrops can be drawn in. Thus in five six-inch quarter sheets alone (30 square miles), over 1,000 bore-journals have been collected by the geologists, while the total number to date in one-inch Sheet 40 is just under 3,000. It can therefore be readily understood that in such ground reasonable finality of mapping is only to be attained after the expenditure of very many times more labour than is required for an equal area of simple structure, such as the Wemyss coalfield to the east.

Mr. Haldane, who during the summer season was detached from the unit to assist in the completion of one-inch Sheet 108 (Altnaharra), resumed Fifeshire work during the autumn in the neighbourhood of Dunfermline and also in the Cleish Hills. Mr. Allan began to join up with Mr. Haldane on his west, and with Mr. Knox on his east, the latter having carried his survey on towards Leslie, Kennoway, and Windygates.

Old Red Sandstone.—The northern boundary fault, and the Old Red Sandstone which outcrops close to its north side, are situated mostly in low-lying tracts which drain into Loch Leven, and are thickly covered with Glacial and Recent deposits. There is little evidence here on which to alter the existing maps.

Calciferous Sandstone Series.—In the area of sediments and associated igneous rocks north of Burntisland, Mr. Knox and Mr. Allan find evidence, around Auchtertool and to the east, of considerable faulting with consequent repetition of individual flows and sheets. The total thickness of these beds from the Charlestown Main Limestone to the Burdiehouse is thus probably much less than the original mapping implies. Nearer Burntisland a number of bore-journals collected by Mr. Knox tends to support his earlier

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conclusion[1] that the lavas of King Alexander's Crag (at Kingswood End) are older than those near the Binn, and further suggests that the plant-bearing limestone[2] above and east of the Crag is on or about the horizon of the Fells Limestone of the Lothian shale-fields. With the help of petrographical evidence, Mr. Knox has been able to show that a large east-and-west fault running through Kirkcaldy passes not, as hitherto supposed, along Raith Lake, but to the north of Castle Hill on its northern shore; the outcrops of neighbouring intrusions thus become susceptible of a more reasonable explanation than before.

In the Cleish Hills to the north Mr. Allan finds that the strata around Dichindad, ¾ mile south-west of Blairadam Station, are not continuous with the coalfield, as previously mapped, but are cut off from it by a powerful east-and-west fracture. A bore here found 45 fms. of sandstone, with a thin coal and some blaes, resting upon the Nivingston Craigs intrusion, 26½ fms. thick, and penetrated 82½ fms. further into sandstone with a little blaes and fireclay—thus proving more than 750 ft. of Calciferous strata. These clearly belong to the Oil Shale Group, evidently developed in greater thickness than had previously been suspected, and probably do not include the highest beds of the group. A band with abundant *Lingula* has been detected in the beds which outcrop below the sill along the foot of the Craigs.

Farther west, in Mr. Haldane's ground, the sandstones which outcrop here and there amid the network of dolerite intrusions, and are exposed in the upper part of the Georgeton Burn near Hardiston (where they contain a poor coal seam), also belong to the Oil Shale Group. Below them are found tuffs and lavas, succeeded by typical Cementstones of Ballagan type. This is probably the most easterly exposure of the last-mentioned strata in this part of Fife; their outcrop is only about 50 yds. wide, and is truncated on the north by the Ochil Fault.

Carboniferous Limestone Series.—South of Blairadam the limestone seen in the Kelty Burn near the axis of the large anticline has been identified by Mr. Allan with the highest or Upper Kinniny Limestone, near the base of the Limestone Coal Group, and a new exposure of this seam has been detected in Drumnagoil Burn, south-east of Blairenbathie farm.

Mr. Haldane continued the revision of the Limestone coalfield in the area west of Dunfermline, and Mr. Allan in the Kelty and Lochgelly districts. No great divergence from the sequence of seams recorded in previous 'Summaries of Progress' has been found. East of Blairenbathie a seam has been mined which is almost certainly the Stink or Sulphur Coal; this seam, which lies about 12 fms. below the Dunfermline Splint, is rarely wrought, but appears in this case to have been mistaken for the latter coal, which is locally much thinner than usual.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 108.
[2] 'Summary of Progress' for 1925 (*Mem. Geol Surv.*), 1926, p. 121.

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In the Dundonald and Cardenden areas of the Lochgelly field it is found that the coal-bearing strata, as well as some of the individual seams, are thinner than to west or to north; still farther to the east, around the nose of the Burntisland anticline, the members of the higher groups of coals are not yet separately recognisable, though the groups themselves can generally be correlated; two important seams, the Glassee and Mynheer, disappear almost completely, while the Dunfermline Splint is represented by a number of thin coals with sandstone partings. It is of interest to note that the well-known Lochgelly Blackband Ironstone passes eastwards into a normal bituminous coal, with a band of parrot, and has been worked near Cardenden as a coal under the name of the Clunie Splint.

The limestones once wrought at Raith, Glenniston and Shaw's Mill quarries appear to be the same seam, and may be correlated with the Charlestown Main limestone. The Upper Limestone Group also occurs east of Cardenden village, but the Index Limestone position, though clearly recognisable in bores, has not been seen anywhere at the surface, nor was it recorded in the shaft of the Minto Pit.

Glacial and Post-Glacial.—North of the Cleish Hills the valleys of the Pow Burn and Gairney Water are, as already mentioned, deeply covered with drift. In the eastern part of their joint valley Mr. Haldane finds wide stretches of gravel, disposed in mounds which often appear to have been subjected to subsequent erosion by the waters of a glacial lake.

At the east end of Loch Gelly Mr. Allan reports that a small area seems to show a definitely morainic topography, and appears to mark the end of a big stretch of more or less continuous sand and gravel partly deposited in alluvial flats, which extends to near Crossgates, five miles to the south-west. North of the River Ore and east of Kinglassie Mr. Knox also finds wide spreads of sand and gravel of considerable thickness. They appear to be of glacial origin, but not to be directly connected with those just mentioned, which are on the whole at a lower level and probably of later date. The story of the deposition of these gravel spreads has yet to be deciphered.

C. H. DINHAM.

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4. NORTH HIGHLANDS

J. E. RICHEY, M.C., B.A., District Geologist.

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In order to complete the primary survey of one-inch Sheet 108 (Altnaharra) during the field season of 1926, it was necessary to add to the strength of the North Highland unit, and accordingly Messrs. G. V. Wilson, L. H. Tonks and W. Anderson were transferred temporarily to Sutherland from their stations in England. Mr. M. Macgregor also took part in the field-work for a few weeks in the early part of the season.

The ground mapped extends from the Moine Thrust about Meall Horn and Loch More on the west to Ben Klibreck and Loch Naver on the east. The most important results of the season's field-work are summarised below, but detailed petrographical work is necessary before these can be fully interpreted. The rocks met with fall into three main categories: (1) siliceous and pelitic schists of the Moine Series; (2) a group of striped hornblendic rocks which occur in force on both sides of Loch Naver; (3) complexes of granite in intimate association with pelitic and siliceous schists.

1. **Moine Series.**—The country-rock of most of the area surveyed is a siliceous granulite of the Moine Series, similar in all important respects to the rocks recently described in detail from the adjacent one-inch Sheets 102 and 103.[1] Pelitic schists, outside the great granulite and schist complexes referred to later, are limited to narrow bands of garnetiferous mica-schist and to one comparatively thick belt of garnetiferous mica-schist with very large staurolite crystals that runs for six miles from Cnoc an Daimh Mòr southwards across the River of Mudale.

Both these rock-types are garnetiferous and show the grade of metamorphism characteristic of the Moine area generally, except along a relatively narrow belt adjacent to the Moine Thrust. Within the limit of the ground mapped this year this belt shows two types of metamorphic phenomena. First, immediately above the Moine Thrust on Meall Horn and elsewhere is a thick mylonite and green schist belt, the metamorphic condition of which must be interpreted as directly due to the post-Cambrian movements. Second, about the

[1] Read, H. H., *in* 'The Geology of Strath Oykell and Lower Loch Shin,' Explanation of Sheet 102 (*Mem. Geol. Surv.*), 1926, pp. 112–140, *and in* 'The Geology of the Country around Golspie,' Explanation of Sheet 103 (*Mem. Geol. Surv.*), 1925, pp. 7–13.

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head of Loch More and northward towards Amhainn an Lòin, the pelitic bands of the Moine Series are represented by soft phyllites without conspicuous garnets, whilst pebbles are readily recognisable in the siliceous bands.

2. **Hornblende Rocks** occurring in the Moine Series.—Certain hornblende rocks—amphibolites and hornblende-schists—occurring as bosses, sills or dykes in the Moine Series, reproduce types of metamorphosed igneous rocks well-known from other parts of Sutherland; these are, however, not very abundant in the region mapped. Of much greater importance is a group of hornblendic rocks which covers considerable areas on both sides of Loch Naver and is found again farther west beyond Loch Meadie. This group consists of striped rocks formed by the alternation of hornblendic, epidotic and quartzo-felspathic laminae together with bands of hornblende-schist, often garnetiferous, lenses of coarse amphibolite and streaks of acid gneisses, both hornblendic and biotitic. More than thirty small bosses of serpentine penetrate the group; these serpentines are marginally sheared and foliated.

The field-relations of the hornblendic rocks to the siliceous granulites of the Moine Series are of the greatest importance. The surveyors who encountered rocks of this group are in agreement on the following points.

(1) Certain quartzo-felspathic granulites interbanded with the hornblendic rocks are indistinguishable from the quartzo-felspathic granulites of the Moine Series.

(2) There is no sign of discordance between the Moine sediments and the hornblendic rocks; on the contrary the two groups appear to pass by transition one into the other.

(3) Both rock groups are affected by a common system of folding.

(4) The metamorphism of similar rock-types in both groups appears to be the same.

Further, though the serpentine bosses are undoubtedly more numerous in the hornblendic group, yet exactly similar bosses occur within the siliceous granulites of the Moine Series. The tentative conclusion that these hornblendic rocks are an integral part of the Moine Series is suggested. There is no doubt that they are a larger development of the hornblendic rocks of Durcha Type recently described in the Memoirs dealing with adjacent areas to the south[1]. The suggestions were there made that the Durcha Hornblendic Rocks were part of the Moine Series and might possibly be to a large degree of sedimentary origin.

3. **Granitic complexes.**—The eastern part of the area surveyed, about Ben Klibreck and the foot of Loch Naver, is formed by a complex of granite and Moine rocks that is an extension of the complexes of Loch Coire and the districts farther south. The

[1] 'The Geology of Strath Oykell and Lower Loch Shin,' Explanation of Sheet 102 (*Mem. Geol. Surv.*), 1926, pp. 144–7; 'The Geology of the Country around Golspie,' Explanation of Sheet 103 (*Mem. Geol. Surv.*), 1925, pp. 18–20.

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2,000-ft. section afforded by the precipitous north-western face of Ben Klibreck shows the following :—

9. Complex of pelitic schist and granite ; garnets and sillimanite abundant (Summit of Ben Klibreck).
8. Injection-zone of pegmatite and granite sheets in a mixed sedimentary series.
7. Thick pegmatite sheets with pelitic relics (Summit of A'Chioch).
6. Semipelitic garnetiferous schists with abundant pegmatite threads.
5. Highly crystalline banded siliceous and semipelitic schists with pegmatite and granite stripes.
4. Narrow belt of hornblende-schists, etc.
3. Siliceous granulites with scarce granite sheets.
2. Thick sheet of pink granite.
1. Dominantly siliceous granulites with rare granite sheets.

Several of these zones established on Ben Klibreck have been followed for considerable distances. For instance, the Pegmatite Zone (No. 7) is traceable from Loch nan Uan for nine miles into Strath Naver, whilst the base of the pelitic schist and granite complex of the summit of Ben Klibreck (No. 9) is known for fifteen miles from Meall Odhar to Strath Naver. Whilst these broad zones can be followed as far as Strath Naver, they show considerable variation in detail at different localities. For example, south and north of the foot of Loch Naver, garnetiferous hornblendic rocks are mixed in the complex, whilst the occurrence of a coarse red granitic rock in considerable bulk in Strath Naver around and south of Syre further complicates matters. With the pelitic schist and granite complex zone (No. 9) the great granite complex of the Loch Coire region is entered. It should be noted that as one ascends higher in the perfectly regular structural sequence on Ben Klibreck one encounters more and more injected igneous material. The structure appears to indicate that along the north-west slope of that mountain there is exposed the floor of a great compound laccolitic intrusion. The relation between the injection of the granitic material and the general metamorphism, and the characters of the abundant mixed rocks formed by injection into various types of country-rock are subjects too dependent upon detailed microscopic investigation to be more than mentioned here.

J. E. RICHEY.

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III. SECTIONAL REPORTS

1.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, SC.D., PH.D., Palaeontologist (District Geologist).
J. PRINGLE, Assistant-Palaeontologist
C. P. CHATWIN, M.SC., Assistant-Palaeontologist } (Senior Geologists).

In Edinburgh

G. W. LEE, D.SC., Senior Geologist.

1. ENGLAND AND WALES

The first volume of the Palaeontological Memoirs is to be brought to completion by the issue of the monograph on ' Plectambonites and some Allied Genera,' by Prof. O. T. Jones, which is now passing through the press.

The new edition of the memoir on the Special Oxford Sheet, by Mr. Pringle, was published in June. It was possible to include in the memoir certain information obtained by Mr. Pringle from road-cuttings made in the course of the widening of the London-Oxford road. In one of these excavations the unconformity between the Corallian and Kimmeridge formations was well displayed.

Fine specimens of ' *Astarte* ' *hartwellensis* (J. de C. Sow.) in the Museum, from the Rotundum and Pallasioides Zones of the Upper Kimmeridge Clay, have been investigated unofficially by Dr. Kitchin, who has discussed the relationships of this well known species and has established for it a new genus, *Hartwellia*.[1] Most of the specimens studied came from the Hartwell Clay and the Swindon Clay. The species is not yet known to occur outside the limits of the above-mentioned zones. The characters of the genus *Hartwellia* link it with the Astartid generic group *Coelastarte*, and it is regarded as a specialized branch not giving rise to descendants. Mr. S. S. Buckman has recently found that another species of *Hartwellia*, as yet undescribed, is present in the sandy Pectinatus Beds of Wheatley, Oxfordshire, underlying the Rotundum Zone. Dr. Kitchin included in his paper some notes on the stratigraphical position of the Hartwell Clay, in agreement with the views on this subject adopted in recent years by the Geological Survey.

In connexion with the work in Surrey on Sheet 285, an endeavour was made to obtain palaeontological evidence for age in the Netley Heath Gravels. A small series of specimens from the ironstone-fragments in the gravels, obtained some years ago by Mr. W. P. D. Stebbing, and presented by him to the Survey, was considerably supplemented by a collection made by Mr. S. W. Hester. On account

[1] Kitchin, F. L., 'A new Genus of Lamellibranchs (*Hartwellia* gen. nov.) from the Upper Kimmeridge Clay of England, with a Note on the position of the Hartwell Clay,' *Ann. Mag. Nat. Hist.*, Ser. 9, vol. xviii, pp. 433–455, pl. xix, Nov., 1926.

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of their position on the North Downs, these gravels have hitherto been considered to represent the Lenham Beds of Kent (Miocene or lowest Pliocene). Mr. Chatwin finds, however, that this fragmentary material contains nothing to identify the deposit with the Lenham Beds; the assemblage is suggestive rather of a fauna of the age of the Red Crag of East Anglia.

Mr. Chatwin has also examined the extensive collection of fossils from the Bargate Stone acquired from the Rev. W. A. Shaw, together with the specimens collected for the Survey by Mr. Hester. The indigenous ammonites of this bed have been shown by Dr. Spath to correspond with the fauna of the Nutfield Beds (late Aptian), the chief species falling within the genus *Parahoplites*. The other indigenous fossils call for no special remark, except to note that the collection includes a beautiful cirripede-capitulum, with the plates united in place, which is under investigation by Mr. T. H. Withers. The derived Jurassic cephalopods comprise many genera from horizons of the Middle and Upper Oxford Clay. Mr. Chatwin has examined the derived fossils of other groups, principally lamellibranchs, and is able to confirm the late C. J. A. Meyer's conclusion that their state of preservation precludes any specific determination.

In the material collected by Mr. Templeman from the Carboniferous Limestone series in North Cumberland and Northumberland, Mr. Pringle has recognized further new species of brachiopods, of the genera *Productus* and *Buxtonia*. It is hoped that these will be described by Miss H. M. Muir-Wood.

Some of the ammonites collected by Messrs. Pringle and Templeman from the Lias of Barrington, Somerset, have been figured by Mr. Buckman, who is studying all the specimens obtained by the Survey from that locality.

Mr. Pringle and Mr. Dixon have prepared as an Appendix (p. 123) an account of the stratigraphical relations of the Penlan Quartzite, which was formerly classified with the Upper Old Red Sandstone. Mr. Pringle has never accepted that classification of the quartzite, and his view that it is of Millstone Grit age is now confirmed. Fragments of silicified wood displaying well preserved structure, which were collected by him from the quartzite many years ago, have now been studied by Mr. J. Walton, who describes and figures the wood in Appendix V (p. 126).

Further work has been done by Mr. S. W. Morgan in preparing a catalogue of the Kidston Collection.

The following specimens in the Museum have been figured, described or mentioned in publications:—

IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1924. (Published 1926).

A Monograph of the Fossil Macrurous Crustacea of England. (Part iii). By MR. H. WOODS, M.A., F.R.S.

Astacodes falcifer *Bell*, pl. ix figs. 2a, b, p. 34.
Pseudoglyphea etalloni *Oppel*, pl. xi, figs. 5a, b, p. 44.
" sp., p. 47.

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A Monograph of the Ammonoidea of the Gault. (Part iv).
By DR. L. F. SPATH, F.G.S.

Dimorphoplites chloris *Spath*, pl. xiii, figs. 1a, b, p. 164.
,, *aff.* tethydis (*Bayle*), pl. xv, fig. 6, p. 166 (2 specimens).
Epihoplites *aff.* trifidus (*Spath*), pl. xv, fig. 9, p. 177.
,, denarius (*J. de C. Sowerby*), p. 179.
,, gibbosus *Spath*, p. 186 (2 specimens).
,, sp. juv. ind., p. 183.
Euhoplites sp. nov. [boloniensis *Spath*], p. 147.

IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, VOLUME CCXV.

Contributions to the knowledge of Lower Carboniferous Plants.
By MR. J. WALTON, M.A., F.G.S.

Telangium bifidum (*Lindley and Hutton*), pl. xvii, fig. 24, p. 217.
Rhacopteris circularis *Walton*, p. 209.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXII.

A Revision of the British Carboniferous Murchisoniidae, with Notes on their Distribution and Descriptions of some New Species.
By MRS. JANE LONGSTAFF, F.L.S., F.G.S.

Murchisonia tenuissima *Donald*, p. 536.
,, zonata *Donald*, p. 536 (2 specimens).
Aclisoides striatula (*de Koninck*), p. 537.
Cerithioides (?) oweni *Donald*, p. 538.
Pithodea percincta (*Portlock*), p. 539.
Hypergonia compacta *Donald*, p. 543.
,, elongata (*Portlock*), p. 544 (2 specimens).
,, quinquecarinata (*de Koninck*), p. 551.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME XVIII, NINTH SERIES.

A new Genus of Lamellibranchs (Hartwellia *gen. nov.*) *from the Upper Kimmeridge Clay of England, with a Note on the position of the Hartwell Clay.*
By DR. F. L. KITCHIN, M.A., F.G.S.

Hartwellia hartwellensis (*J. de C. Sowerby*), pl. xix, figs. 1–5, p. 440 (4 specimens).

IN THE GEOLOGICAL MAGAZINE, VOLUME LXIII.

Studies in the Corallian Lamellibranch Fauna of Oxford, Berks., and Wilts.
By MR. W. J. ARKELL, B.A., F.G.S.

Lima (Plagiostoma) zonata *Arkell*, pl. xxii, figs. 1, 2, p. 119 (5 specimens).
,, ,, laeviuscula (*J. Sowerby*), p. 200.
Ctenostreon sp., p. 208 (2 specimens).
Entolium solidum (*Roemer*), p. 536.
Chlamys nattheimensis (*De Loriol*), p. 537 (3 specimens).
,, splendens (*Dollfuss*), p. 540.
Aequipecten inaequicostatus (*Phillips*), p. 545 (2 specimens).
Velopecten velatus (*Goldfuss*), p. 550 (2 specimens).

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IN THE PROCEEDINGS OF THE GEOLOGISTS' ASSOCIATION, VOLUME XXXVII.

On the Zones of the Cenomanian and the Upper Albian.
By DR. L. F. SPATH, F.G.S.

Schloenbachia subvarians *Spath, var.* densicostata *Spath*, p. 430.

IN THE MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY, VOLUME LXX.

Some Notes on the Genus Actinophyllum.

By MR. S. H. STRAW, M.Sc., F.G.S.

Actinophyllum plicatum *Phillips*, pl., figs. 1a, 1b, 5, p. 134.

IN THE TRANSACTIONS OF THE ROYAL SOCIETY OF EDINBURGH, VOLUME LIV. Part iii. (No. 21).

Contributions to the Study of the Old Red Sandstone of Scotland. V. On the Identification of the large "Stems" in the Carmyllie Beds of the Lower Old Red Sandstone as Nematophyton.

By PROF. W. H. LANG, D.Sc., F.R.S.

Nematophyton caledonianum *Lang*, pl. ii, fig. 12, p. 794.
Cf. ,, forfarense (*Kidston*), pl. ii, figs. 25, 26, p. 797.

IN TYPE AMMONITES, VOLUME VI.

By MR. S. S. BUCKMAN, F.G.S.

Kerberites kerberus *S. Buckman*, pl. dxxA; pl. dxxB, figs. 1, 1a, 2.
Bikosmokeras geminatum *S. Buckman*, pl. dcxxv, figs. 1–3.
Allovirgatites distans (*Neaverson*), pl. dcxxxviiiA; pl. dcxxxviiiB.
,, tutcheri *Neaverson*, pl. dcxcii, figs. 1–3.
Proplanulites laboratus *S. Buckman*, pl. dcxlv.
Arcidactylites arcus *S. Buckman*, pl. dclvii, figs. 1–3.
Hildoceratoides serpentinus (*Reinecke*), pl. cxxxviiic, figs. 1, 2.
Harpoceras falcula *S. Buckman*, pl. dclxxii, figs. 1, 2.
Xeinodactylites sp., p. 41.
Anguidactylites anguiformis *S. Buckman*, p. 41.
Nodicoeloceras crassoides (*Simpson*), p. 42.
Crassicoeloceras pingue *S. Buckman*, p. 42.
Vermidactylites sp., p. 42.
Toxodactylites toxophorus *S. Buckman*, p. 42.
Leptodactylites leptum *S. Buckman*, p. 42.
Spinicoeloceras spicatum *S. Buckman*, p. 42.
Lobodactylites lobatum *S. Buckman*, p. 42.
Peridactylites consimilis *S. Buckman*, p. 42.
Multicoeloceras multum *S. Buckman*, p. 42.

IN MEMOIRS OF THE GEOLOGICAL SURVEY.

SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN AND THE MUSEUM OF PRACTICAL GEOLOGY FOR THE YEAR 1925.

Appendix VII.—*On a New Species of* Phyllobrissus *from a deep boring at Virginia Water, Surrey.*

By PROF. H. L. HAWKINS, D.Sc., F.G.S.

Phyllobrissus artesianus *Hawkins*, text-fig. 23, p. 190 (2 specimens).

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Appendix VIII.—*New Goniatites from the Millstone Grit of Lancashire.*

By Mr. W. B. Wright, M.I.M.E., F.G.S.

Reticuloceras reticulatum, *early mut.* γ, *mut. nov.*, pl. xii, figs. 1, 2, 6, p. 194 (8 specimens).
Gastrioceras lineatum *Wright*, pl. xii, figs. 3, 4, 8, p. 196 (7 specimens).
Gastrioceras? sigma *Wright*, pl. xii, figs. 5, 7, p. 197 (14 specimens).

2. Scotland

Dr. Lee reports that the fossils obtained from natural exposures were collected primarily for the purpose of the current Survey, and did not lend themselves to purely systematic research-work. The examination of fossils obtained from the cores of borings has continued to prove of practical value, and reference to some of the borings will be found elsewhere in this volume.

An interesting suite of fossiliferous Chalk flints from the Drift of Aberdeenshire was studied and named by Dr. Lee, in occasional consultation with members of the palaeontological staff in London. This collection, made by Mr. Alex. Insh, of Peterhead, whose search extended over a number of years, was presented to the Survey through the kind offices of Mr. J. Duncan, late of the Royal Scottish Museum.

The chief value of the collection lies in its generally good state of preservation and in the large number of species represented, amounting to no less than 58. This probably exceeds the number of Chalk forms found in the Drift at any single English locality. The species are for the most part well known, and they indicate the presence in the North Sea Chalk of most of the life-zones from that of *Holaster planus* to that of *Belemnitella mucronata* inclusive, the only apparent exception being that of *Marsupites*. The groups represented belong to the sponges, corals, crinoids, echinids, worms, Bryozoa, brachiopods, lamellibranchs and gasteropods. Of these the most conspicuous are the lamellibranchs, echinids and brachiopods, represented by 19, 14 and 9 species respectively. It must be noted that this fauna shows a West of Europe facies, though its origin is so much more northerly than the typical districts of England and of the Continent. The only suggestion of a northern influence rests on the determination of a single specimen of a *Pecten*, referred to *P. membranaceus* Nilsson, a Scanian form.

F. L. Kitchin.

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2.—PALAEOBOTANICAL WORK.

Dr. R. Crookall commenced duties on August 23rd, 1926, and was detailed for palaeobotanical work. A large proportion of his time has been occupied with work on the Kidston Collection of Carboniferous plants, numbering approximately 7,000 specimens. A comprehensive catalogue of this collection is in course of preparation, and he has been engaged in checking the collection with the manuscript slip-catalogue prepared by Mr. S. W. Morgan. The completed catalogue will include, with the list of specimens, details as to the exact horizon and locality, and bibliographic references if figured or described.

In September and October, while receiving instruction in field-methods and mapping from the officers of the Fife unit, Dr. Crookall collected fossil plants at various localities in the Fifeshire coalfield. While in that district he also visited and examined the cores of a bore at Cupar with Mr. C. H. Dinham, and drew up a number of bore-records.

In examining various specimens of fossil woods, etc., he has prepared 70 microscope slides and taken 14 photomicrographs.

Fossil woods from the Pennant Rock (Staffordian Series) of the South Wales and the Bristol and Somerset coalfields, an horizon from which petrified fossil plants have not hitherto been described, have been investigated. Most of the specimens consist of secondary wood only of the Araucarian type, and they are frequently badly preserved. The flora is found, however, to include species of *Mesoxylon*, *Sutcliffia*, *Psaronius*, *Calamites* and *Lepidodendron*, the commonest form being *Mesoxylon*. Several new species of plants have been noted, one of which is now described in Appendix XI.

Petrified plant material from the Calciferous Sandstone Series of King Alexander's Crag, near Pettycur, Fife, examined by Dr. Crookall, proved to contain fern-petioles, species of *Lepidodendron*, etc.

Specimens of silicified fossil wood from the Lower Greensand of Shere, Surrey, collected by Sir Francis Ogilvie, have also been sectioned, and the wood found to consist entirely of pycnoxylic secondary xylem with almost invariably uniseriate xylem-rays. The pitting on the walls of the tracheids and ray cells is not preserved, but the specimens evidently represent Coniferous wood. Attention has also been paid to some fragmentary remains of doubtful affinity collected by Miss E. M. Lind Hendriks in the Falmouth Beds near Gunwalloe Fishing Village, Cornwall.

R. CROOKALL.

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3.—PETROGRAPHICAL WORK

The work of the Petrographical Department has been mainly connected with the areas now being, or recently, surveyed.

Special attention was directed during the past year to the petrography of the igneous rocks of the Berwyn Hills, and the Petrographer visited the district with Dr. Bernard Smith. All the rocks of igneous origin, whether they be interbedded, or form masses that present transgressive boundaries to the Upper Ordovician rocks with which they are associated, show an unmistakable albitic facies. There is considerable unconformity in their composition and also, to a less degree, in their structure. The outstanding character, however, is the predominance of albite or albite-oligoclase over any other variety of felspar, a feature that indicates a high content of soda, and that causes the rocks to be classed with the soda-rhyolites, keratophyres, and albite-porphyrites. This albitic suite of rocks characterizes a Lower Palaeozoic vulcanicity throughout Wales, for identical rocks are encountered as sills, lavas, and tuffs in the Ordovician of Pembrokeshire as at Fishguard, Abereiddy, Abercastle, Sealyham and the Prescelly Hills; and in North Wales in Cader Idris, the Arrans, Arenig and Snowdonia. In some cases there is reason to infer that the entirely albitic character of these rocks is due, in a measure, to superinduced albitization; and that, in their original condition, some of them had had an andesitic or even basaltic composition. This, however, appears to be the exception rather than the rule, and the logical conclusion is that the albitic character is largely original. Even when albitization can be shown to have taken place, this change cannot wholly be dissociated from the normal processes of solidification and cooling of the rock in question. In the case of the pyroclastic rocks and those igneous rocks which have suffered brecciation in the Berwyn Hills it is obvious that the albitic character was fully established before the disruption took place.

The petrography of the rocks of the Berwyn Hills will be dealt with in detail in the forthcoming memoir on the Oswestry district, but two of the larger masses, namely those of the Bryn and Moelydd, call for special comment.

In the neighbourhood of Bryn, to the south-west of Oswestry, occurs the largest outcrop of igneous rock in the district. It is certainly intrusive, as is shown by its relation to the rocks with which it comes in contact, but it is especially interesting on account of the intense shattering and brecciation that have affected a large portion of the mass.

There are ample signs of explosive shattering without much displacement of the resulting fragments, as well as more obvious brecciation accompanied by movement; but it is clear that this fragmental character of the rock is related to the process of intrusion,

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and is unconnected with any faulting, or folding, which has affected the surrounding sedimentary deposits. The conclusion is, therefore, that the breccias are of the nature of vent agglomerates formed as the result of an effort on the part of unconsolidated magma to find a vent, or vents, through an already solid plug.

The rock that forms the bulk of the Bryn mass is a moderately fine-grained, grey to green, keratophyre, with minute phenocrysts of albite-oligoclase and augite in an albitic microlithic base. Locally, as at Bryn-uchaf, it becomes slightly coarser in texture, and has more definitely the characters of a hypabyssal rock.

The Moelydd mass, which, like the Bryn mass, passes eastward beneath the Carboniferous rocks, is of a similar nature, and shows the same signs of shattering and brecciation. The brecciation is well displayed in the crags overlooking the Nant and in the exposures of the northern part of the mass.

It is probable, therefore, that in the masses of Bryn and Moelydd we have the remains of vents of late Ordovician age.

HERBERT H. THOMAS.

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4.—CHEMICAL WORK

During 1926 the quantitative analyses reported by the Chemical Department were entirely for the Scottish Memoirs, and include the following :—

819. *Quartz-gabbro* (Tertiary). E. end of central vent, Gleann Dubh, 3 m. S.W. of Brodick. Arran. Slice No. S24355.

820. *Coarse Biotite-granite*. Northern boss, Glen Rosie Water, ½ m. above confluence with Garbh Allt. Arran. Slice No. S24380.

821. *Diorite*. Plutonic intrusion of Lower Old Red Sandstone age, part of Distinkhorn Complex. Avon Water, S.E. bank, 700 ft. above junction with Powmeadow Burn. Ayrshire. Slice No. S24392.

822. *Phonolitic Trachyte* with fresh nepheline. Intrusion of Calciferous Sandstone age. Quarry, 400 yds. W. of Underlaw, about 2 m. E.N.E. of Darvel. Ayrshire. Slice No. S24393.

823. *Felsite*. Dyke. Gleann Dubh Water, 100 yds. above confluence with Glen Ormidale Water, 825 yds. W. 37° S. of Kilmichael, Brodick. Arran. Slice No. S24453.

Lab. Nos.	819	820	821	822	823
SiO_2	52·43	74·87	55·57	57·67	69·26
Al_2O_3	13·50	11·24	15·94	17·72	11·60
Fe_2O_3 ...	4·93	0·34	0·85	2·28	1·31
FeO	7·00	1·22	5·90	3·34	2·57
MgO	4·61	0·22	4·24	2·01	1·10
CaO	8·25	1·30	5·07	1·68	2·61
Na_2O	3·27	3·31	3·09	6·40	2·08
K_2O	1·08	5·68	5·14	5·08	3·88
$H_2O > 105°$ ...	1·64	0·49	1·29	1·16	1·61
$H_2O < 105°$ ...	0·28	0·29	0·29	0·62	1·67
TiO_2	1·91	0·26	1·42	1·07	0·45
P_2O_5	0·21	0·09	0·21	0·25	0·10
MnO	0·20	0·05	0·15	0·15	0·45
CO_2	0·08	0·49	0·40	0·23	1·76
ZrO_2	0·00	—	—	0·01	—
FeS_2	0·44	0·33	0·44	0·17	0·00
Cr_2O_3	0·02	0·02	0·02	0·01	—
NiO, CoO ...	—	—	—	—	0·00
BaO	0·06	0·04	0·03	0·06	0·00
Li_2O	0·00	0·00	0·00 ?	0·00	0·00
Totals ...	99·91	100·24	100·05	99·91	100·45
Analysed by...	B. E. Dixon.				E. G. Radley.

0·00 ? = 'Trace'; 0·00 = 'Not found.'

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824. *Granophyric Granite.* Quarry in bank of Allt nan Dris, 1,000 ft. N. of Derenenach. Arran. Slice No. S24454.

825. *Diorite.* Quarry at bridge over Allt nan Calaman, at roadside, Gleann ant-Suidhe, 2 m. 550 yds. W. 24° S. of Brodick Church. Arran. Slice No. S24455.

826. *Hypersthene-dolerite.* Sill. Shore at foot of Struey Falls. Bennan Head. Arran. Slice No. S24457.

827. *Felsite.* Waterfall in the Allt Dhepin, ½ m. S.S.W. of Loch na Leirg, Whiting Bay. Arran. Slice No. S24458.

828. *Quartz-dolerite.* Sill. Gorge in Allt Dhepin. Cnoc an Fheidh. Whiting Bay. Arran. Slice No. S24459.

Lab. Nos.	824	825	826	827	828
SiO_2	75·65	53·67	54·83	71·58	54·00
Al_2O_3	11·89	15·47	14·10	12·20	13·09
Fe_2O_3 ...	1·19	3·24	3·57	1·51	3·53
FeO	1·02	7·25	5·87	1·77	8·45
MgO	0·15	4·90	4·88	0·50	3·49
CaO	0·91	8·28	7·90	1·98	5·55
Na_2O	3·44	2·77	2·32	2·83	3·27
K_2O	4·26	0·80	1·73	3·86	1·80
$H_2O < 105°$ ...	0·40	0·23	1·23	0·76	1·71
$H_2O > 105°$ ...	0·41	1·73	0·48	1·10	1·26
TiO_2	0·28	1·28	0·74	0·44	2·83
P_2O_5	0·16	0·21	0·24	0·13	0·31
MnO	0·26	0·31	0·37	0·31	0·37
CO_2	0·09	0·04	1·90	1·07	0·25
FeS_2	0·00	0·00	0·00	0·00	0·14
NiO, CoO ...	0·02	0·04	0·03	0·00	0·00
BaO	0·03	0·04	0·00	0·00	0·02
Li_2O	0·00	0·00	0·00 ?	0·00 ?	0·00 ?
Totals ...	100·16	100·26	100·19	100·04	100·07
Analysed by	E. G. Radley.				

829. *Quartz-felspar-porphyry.* Sill. Quarry ½ m. W.S.W. of Levencorroch. Arran. Slice No. S24460.

830. *Crinanite.* Sill. On shore, 340 yds. N. 90° W. of Clauchlands Point. Arran. Slice No. S24456.

831. *Riebeckite-orthophyre.* Sill. Middle escarpment. Creagliath, ½ m. N. by E.N.E. of lighthouse on S.W. point of Holy Island. Slice No. S24461.

834. *Olivine-basalt of Dalmeny Type.* Lava of Calciferous Sandstone age. Quarry 230 yds. S. of Dalmeny Church. Linlithgowshire. Slice No. S25062.

835. *Olivine-basalt allied to Dalmeny Type.* Lava of Millstone Grit age. Quarry left of Annick Water, 700 ft. E. 35° S. of Rashillhouse. Ayrshire. Slice No. S25065.

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Lab. Nos.	829	830	831	834	835
SiO_2	75·22	44·68	68·38	46·24	46·16
Al_2O_3	12·22	16·37	15·87	13·83	13·60
Fe_2O_3 ...	2·30	4·31	1·02	1·92	3·19
FeO	0·22	8·11	1·42	9·36	9·39
MgO	0·06	6·59	0·04	9·51	8·84
CaO	0·84	8·70	1·04	10·06	9·41
Na_2O	2·22	3·28	5·70	2·53	2·81
K_2O	4·94	0·21	4·65	1·71	1·36
$H_2O > 105°$ ...	0·72	2·99	0·30	0·71	1·52•
$H_2O < 105°$ ...	0·52	1·69	0·56	0·32	0·37
TiO_2	0·28	2·51	0·24	2·54	2·36
P_2O_5	0·18	0·15	0·26	0·47	0·47
MnO	0·25	0·32	0·37	0·15	0·15
CO_2	0·03	0·06	0·04	0·63	0·12
ZrO_2	—	—	0·06	—	—
FeS_2	0·00	0·00	0·00	0·15	0·08
Fe_7S_8	—	—	—	0·00 ?	0·00 ?
Cr_2O_3	—	—	—	0·02	0·01
NiO, CoO ...	0·00	0·05	0·03	—	—
BaO	0·00	0·02	0·03	0·00 ?	0·04
Li_2O	0·00 ?	0·00	0·00	0·00 ?	0·00 ?
Totals	100·00	100·04	100·01	100·15	99·88
Analysed by	E. G. Radley.			B. E. Dixon.	

The commoner difficulties attendant upon the rapid determination of phosphorus in coal ashes were clearly shown by the investigation undertaken for the Fuel Research Board to be caused by the presence of such elements as arsenic, titanium and vanadium. With regard to the last mentioned impurity, an American investigator has published a method[1] which appears to be satisfactory; while arsenic and titanium, as well as silica, can be effectively prevented from causing trouble by the use of the method published in the Board's Final Report on the Analysis of Coal.

R. Sutcliffe.

[1] Johnson, C. M., *Journ. Ind. Eng. Chem.*, vol. xi, 1919, p. 113; *Chemical News*, vol. cxviii, 1919, p. 113.

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IV. MUSEUM OF PRACTICAL GEOLOGY

At the beginning of the year it was found that fresh supports to the roof and side-galleries were necessary. The Museum was once more closed to the public on February 22nd, and on completion of the repairs was reopened on April 19th.

Additional educational sets of maps and photographs have been installed, amongst which may be mentioned an interesting series showing all the stages in the production of a one-inch geological map. Progress has been made with the adequate illustration of the geology of the London district. A large, hand-coloured, geological map of the area, prepared in the drawing office, has been framed and hung on the wall adjacent to the London model. It is supplemented by one-inch maps, photographs and large scale vertical sections and, although the exhibit is not yet complete, it has already attracted considerable attention.

The exhibits of large specimens on the ground floor and main staircases have been completely reorganized; many of them have been stored and their places taken by more suitable and attractive specimens, prominent amongst which are two large, polished slabs of Burmese jadeite displaying most of the tints found in that interesting mineral.

During the year the Museum staff prepared special exhibits for the British Association meeting at Oxford, the Geologists' Association Exhibition, and for the Jubilee Congress of the Mineralogical Society, the members of which were received by the Director in the Museum.

A most noteworthy addition to the collections was made during the year when Mrs. Jones and Mr. Gilbert Lindsey jointly presented the collection of minerals and rocks made by their father, the late C. R. Lindsey, Esq., B.Sc. The collection comprises about 8,000 mineral specimens, many of them particularly well crystallized examples of species found in Britain, and 2,000 rocks with the accompanying micro-sections. Since the Ludlam Bequest this is perhaps the most important single addition to the Mineral collection and will prove of the greatest use for purposes of exhibition and research. The collection is at present housed in cabinets in the crypt but a selected series of the best British specimens will be put on exhibition as soon as possible.

In the Mineral Department progress has been made with the registration of stored material and additional exhibits of iron ores to illustrate Vol. XXIX of the 'Special Reports' have been completed. Recent acquisitions include fine examples of golden beryl, red tourmaline, and a set of three large models in quartz to illustrate the chief forms used for cut gemstones; also an example of the furnace and materials used for the manufacture of sapphires, presented by Mr. B. J. Tully, F.G.S.

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A large number of additions have been made to the Library, which continues to be used by the public and the staff to an increasing degree. Noteworthy amongst these acquisitions are a collection of manuscripts and maps formerly the property of the late F. W. Harmer, presented by Sir S. F. Harmer; collections of reports and maps (received in exchange), from the Geological Surveys of Colorado, Texas and West Virginia; representative maps (1 : 1,000,000) with manuscript geology, issued by the Norwegian Geological Survey; and a series of geological maps (1 : 50,000) of Chosen (Korea), after the model of the United States Geological Survey Folio Atlases, issued by the Geological Survey of the Government General of Chosen.

W. F. P McLintock.

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APPENDIX I

The Highest Silurian Rocks of the Wenlock District

By T. Robertson, Ph.D.

Text-figures 1, 2, 3, 4.

1. Introduction

The earliest description of the highest Silurian rocks of the Wenlock district is that by Prestwich,[1] who gives a short but clear account of their occurrence. At a later date G. E. Roberts and J. Randall[2] gave a description of some of the higher beds in the Linley Brook section. Since this, no further work has been done on these rocks. It is of importance therefore to ascertain the succession in this area and to compare it with that at Ludlow. In addition, the work of the Survey in the western Midlands has now reached the point at which it is necessary to decide in what position the junction of the Silurian and Devonian systems should in future be drawn on the maps. The conclusion favoured by the writer is that which has been advocated recently in several quarters, namely, that the Ludlow Bone Bed is the most convenient base for the Devonian in the Welsh Borderland; but there are several aspects of the question which may benefit by further investigation.

The fossils mentioned throughout this Appendix were determined in the palaeontological department by Mr. J. Pringle.

2. The Succession in the Wenlock District

The localities in question are shown in Figs. 1 and 2. They consist of inliers in the valleys of the Dean and Linley Brooks, and of the northernmost end of the Silurian dip-slope of Corvedale. The Silurian rocks are succeeded conformably by the Downtonian; whilst both Silurian and Downtonian are overlain unconformably by the Carboniferous rocks of the Coalbrookdale coalfield.

The structure of the ground is simple. A system of folding, which commenced to act on the Silurian rocks before the deposition of the Coal Measures, and continued during and after Coal Measure times, has produced a series of nearly symmetrical north-east and south-west folds in these beds. The most south-eastern anticline exposed is that which brings to the surface the Temeside Group in Linley Brook and the Aymestry Group near the mouth of Dean Brook. The succeeding anticline to the north-west exposes the Aymestry Group between Willey and the Dean. Its effect is supple-

[1] 'On the Geology of Coalbrookdale,' *Trans. Geol. Soc.*, ser. 2, vol. v, 1837, pp. 413–95.

[2] 'On the Upper Silurian Passage-beds at Linley, Salop,' *Quart. Journ. Geol. Soc.*, vol. xix, 1863, pp. 229–32.

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mented on each side by a fault. The south-eastern limb of the next fold is the long scarp running parallel to Wenlock Edge from Posenhall to Norton Camp.

The generalized succession and proposed grouping are given below :—

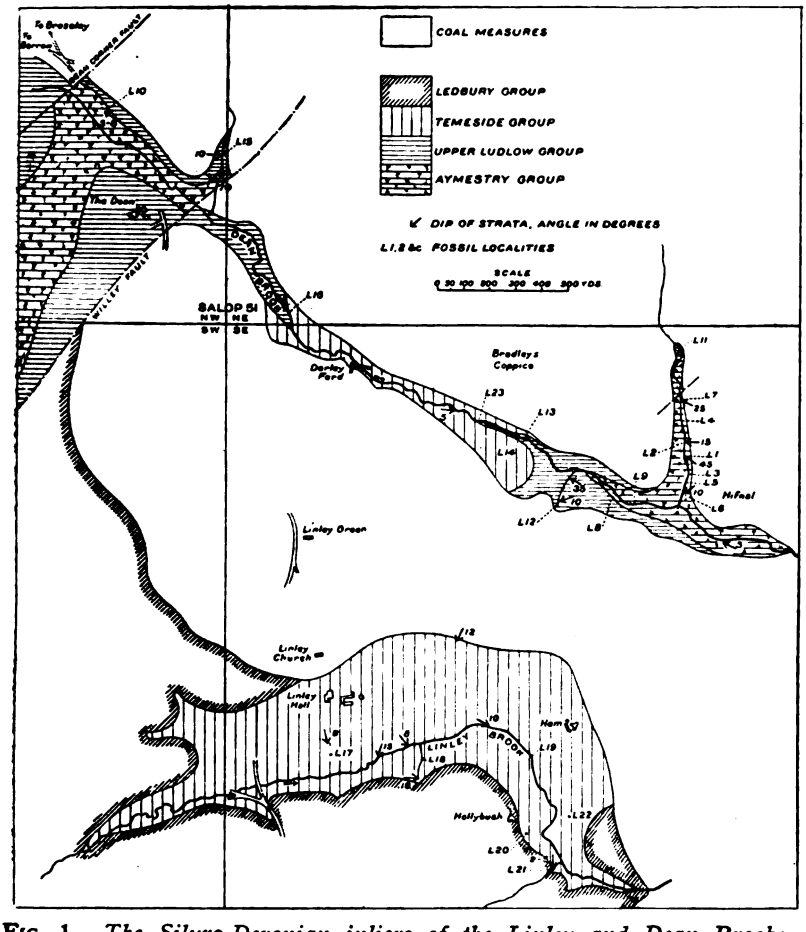

FIG. 1.—*The Siluro-Devonian inliers of the Linley and Dean Brooks.*

	Thickness in Ft.
Downtonian :—	
Ledbury Group : reddish-brown to purple mudstones, mottled with grey or green, and containing bands of brown and speckled grey sandstone, with fish fragments and plant-remains. Seen in the vicinity to ...	200
Temeside Group :—	
Temeside Shales : grey to olive mudstones and sandstones, with one or more bands of dark-red mudstone	90
Downton Castle Sandstone : yellowish sandstone and sandy shales, with several calcareous bands...	30
Ludlow Bone Bed horizon	—

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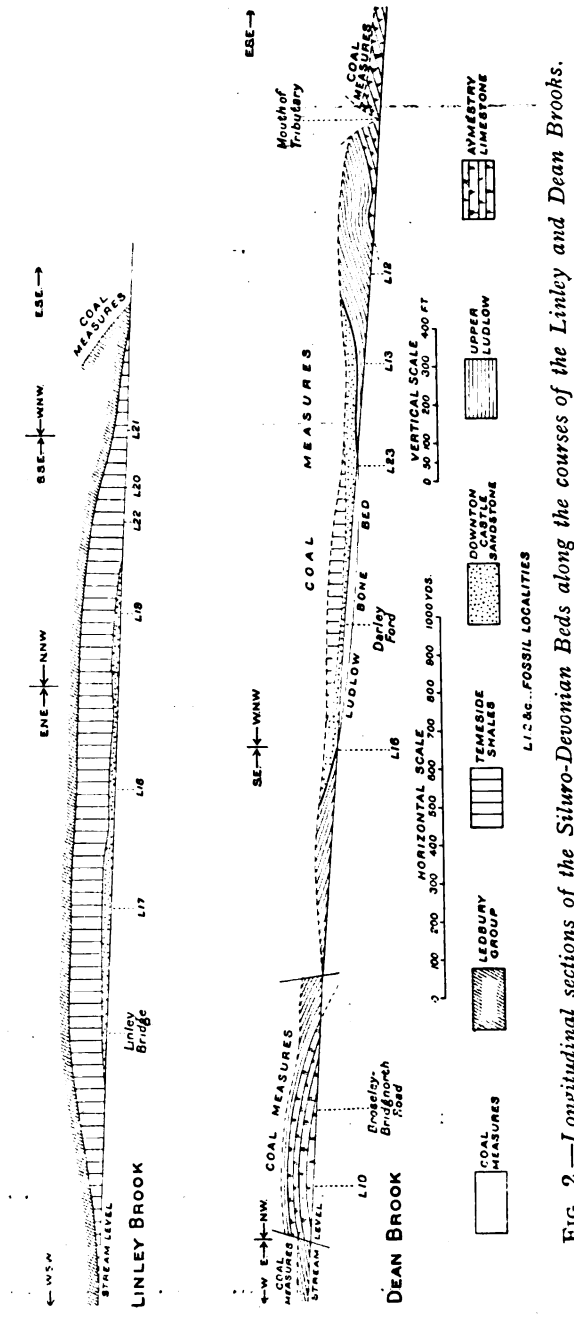

FIG. 2.—*Longitudinal sections of the Siluro-Devonian Beds along the courses of the Linley and Dean Brooks.*

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	Thickness in Ft.
Ludlow :—	
Upper Ludlow Group: calcareous sandy shales with *Camarotoechia nucula*, *Chonetes striatella*, and other characteristic brachiopods, lamellibranchs, etc. ...	100
Aymestry Group: calcareous mudstones; *Wilsonia wilsoni* abundant near the top; *Atrypa reticularis* and *Sieberella galeata* common below	80 to 100

Aymestry Group.—Exposures of these beds occur (1) in the valley of Dean Brook, between Bradley's Coppice and Hifnal; (2) along the axis of an anticline between Willey and the Dean; (3) three quarters of a mile from Much Wenlock, on the road to Barrow; and (4) half a mile from Much Wenlock, on the road to Bourton. The base of the group is everywhere concealed.

(1) *Dean Brook.*—Rocks of the Aymestry Group form the bed of Dean Brook for approximately the last half mile of its course, including the small tributary that enters the brook between Bradley's Coppice and Hifnal. The section in this latter is the most nearly complete in the district, but whilst the area was being surveyed it was somewhat obscured owing to timber-felling operations. The lowest beds exposed are those at L. 1. They are situated on the axis of an anticline pitching to the west, and are probably within 20 ft. of the base of the group. They consist of nodular calcareous mudstones, mottled purple and green. The lowest 20 ft. or so of the exposed sequence yielded the following fauna (L. 1, 2 and 3). Forms marked with an asterisk are very common.

*Cyathophyllum *cf.* angustatum *E. & H.*
*Atrypa reticularis (*Linn.*)
Orthis (Dalmanella) sp.
Sieberella galeata (*Dalm.*)
Slava interrupta (*J. de C. Sow.*)
*Strophonella euglypha (*His.*)
Wilsonia sp.
Cyclonema subsulcatum ? (*His.*)
Loxonema ?
Oriostoma sculptum (*J. de C. Sow.*)
Dalmanites caudatus (*Brünn.*)

Some 10 ft. above this in the sequence lies a definite zone of similar rock with abundant specimens of *Sieberella galeata* (L. 4 and 5). It gave the following forms :—

'Petraia' bina (*Lonsd.*)
Syringopora fascicularis (*Linn.*)
*Atrypa reticularis (*Linn.*)
Leptaena rhomboidalis (*Wilck.*)
Meristina tumida ? (*Dalm.*)
Orthis (Dalmanella) sp.
*Sieberella galeata (*Dalm.*)
Spirifer plicatellus (*Linn.*)
Strophonella euglypha (*His.*)
Wilsonia wilsoni (*J. Sow.*)
Cyclonema subsulcatum (*His.*)
Murchisonia lloydi (*J. de C. Sow.*)
Dalmanites *cf.* caudatus (*Brünn.*)
Proetus sp.

This pentamerid band occupies a similar position at Much Wenlock. In the locality under discussion it is succeeded by about 12 ft. of calcareous blue mudstones yielding the following assemblage (L. 6) :—

Favosites forbesi *E. and H.*
Atrypa reticularis (*Linn.*)
Orthis (Dalmanella) canaliculata *Lindst.*
Orthis (Dalmanella) sp.
Stropheodonta filosa (*J. de C. Sow.*)
Strophonella euglypha (*His.*)
Wilsonia wilsoni (*J. Sow.*)

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Orthonota ?
Pterinea reticulata (*J. de C. Sow.*)
Loxonema ?
Murchisonia lloydi (*J. de C. Sow.*)
Oriostoma sculptum (*J. de C. Sow.*)
Platyceras cornutum (*His.*)
Cyrtoceras sp.
Orthoceras sp.
Dalmanites caudatus (*Brünn.*)
Dalmanites sp.

Then come about 5 ft. of beds with numerous bryozoa and also the following :—

Camarotoechia nucula (*J. de C. Sow.*)
Leptaena rhomboidalis (*Wilck.*)
Lingula sp.
Orthis (Dalmanella) sp.
Slava interrupta (*J. de C. Sow.*)
Stropheodonta *cf.* filosa (*J. de C. Sow.*)
Strophonella euglypha (*His.*)
Murchisonia lloydi (*J. de C. Sow.*)

Above this are beds with abundant specimens of *Wilsonia wilsoni*. These are indicative of the higher portion of the Aymestry Group throughout the district. They appear to be about 10 ft. thick at L. 7 in the tributary section, and are exposed also in Dean Brook itself at L. 8 and 9. The fauna collected from these localities includes the following :—

Favosites ?
Palaeocyclus *cf.* porpita (*Linn.*)
Crinoid ossicles
Atrypa reticularis (*Linn.*)
Chonetes *cf.* striatella (*Dalm.*)
Leptaena rhomboidalis (*Wilck.*)
Orthis (Dalmanella) sp.
Wilsonia wilsoni (*J. Sow.*)
Murchisonia ?
Cyrtoceras ?
Orthoceras angulatum *Wahl.*

In the tributary these beds are repeated by a fault. They are succeeded by between 30 and 40 ft. of nodular beds with a similar but less abundant fauna, and then by the Upper Ludlow flags, there being no development of the Dayia Shales.

(2) *Willey and The Dean.*—Here the Aymestry beds are exposed in the core of a faulted anticline, and they are best seen at the Dean, in the cutting on the road from Broseley to Bridgnorth. About 20 ft. of strata in the higher part of the sequence are exposed here, and contain bands with numerous specimens of *Wilsonia wilsoni*. The following fossils were collected here (L. 10) :—

Cyathophyllum sp.
Favosites forbesi *E. and H.*
Syringopora sp.
Atrypa reticularis (*Linn.*)
Camarotoechia nucula (*J. de C. Sow.*)
Hindella (Whitfieldella) didyma (*Dalm.*)
Lingula lewisi *J. de C. Sow.*
Wilsonia wilsoni (*J. Sow.*)
Orthonota amygdalina (*J. de C. Sow.*)
Cyclonema subsulcatum ? (*His.*)

Towards the top *Dayia navicula* occurs, but very sparingly, and *Delthyris elevata* also was found. The base of the Upper Ludlow is probably about 20 ft. above the top of the section, and is to be seen in a small tributary of Dean Brook, a quarter of a mile to the south-east.

At Willey Old Hall the highest beds of the Aymestry Group are again exposed, and show the characteristic fauna.

(3) *Much Wenlock.*—Although the Aymestry Group forms a conspicuous scarp on the east and south of Much Wenlock, there is no natural exposure of any importance, so that we are entirely dependent upon road-cuttings for information.

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Three quarters of a mile east of Much Wenlock the road to Barrow crosses the Aymestry scarp and possibly 30 ft. of rubbly calcareous mudstones are poorly exposed. About the middle of the exposure the following forms occur, along with many small cyathophyllid corals and gasteropods :—

Atrypa reticularis (*Linn.*)	Orthis (Dalmanella) sp.
Hindella (Whitfieldella) didyma (*Dalm.*)	? Sieberella galeata (*Dalm.*)
Meristina sp.	Wilsonia wilsoni (*J. Sow.*)

They suggest a horizon in the middle of the group, e.g., that of L. 4. The highest beds show abundant *Wilsonia wilsoni* and *Camarotoechia nucula*, thus permitting confident correlation with the Dean Brook section.

The road from Much Wenlock to Bourton and Ludlow gives another section of the group. The beds exposed are in a fault-trough, which crosses the road obliquely about half a mile from Wenlock church (Fig. 4). The dip is west at about 30° and the top 40 ft. or so of the group are shown ; but accurate measurements are difficult to obtain. The lowest beds of the section are nodular bands of limestone in mudstone, with scanty fossils ; but about 15 to 20 ft. above the bottom the typical fauna of the middle portion is to be found, including *Sieberella galeata*, a large form of *Atrypa reticularis*, *Lingula lewisi*, and cyathophyllid corals. Some 10 to 15 ft. farther up the higher zone is well exposed, with abundance of *Camarotoechia nucula*, *Chonetes striatella*, *Orthis lunata* and *Wilsonia wilsoni* ; also *Dinophyllum?*, *Delthyris elevata* (Dalm.), *Lingula lewisi* J. de C. Sow. and *Holopella* cf. *obsoleta* J. de C. Sow. The more flaggy and sandy bands contain *Monograptus leintwardinensis* Lapw. and disc-like bodies resembling minute *Pachytheca*. The junction with the Upper Ludlow beds is not well exposed. About a quarter of a mile farther along the road from Much Wenlock the beds of the middle portion of the group are again exposed, on the outside of the fault-trough.

Upper Ludlow Group.—These beds, with their characteristic fauna, are approximately 100 ft. thick throughout the Wenlock district. In the Dean Brook area they are well shown in the tributary between Bradley's Coppice and Hifnal, above the Aymestry group ; some 50 ft. of strata being exposed below the Coal Measures (L. 11). Fish-spines were found in the Upper Ludlow beds at this locality. At L. 12 possibly 80 ft. of Upper Ludlow beds are exposed in a steep-sided tributary of Dean Brook. When fresh they are olive-green to grey sandy shales with calcareous bands. The junction with the Aymestry beds is concealed, and there is reason to suspect that the fault seen at L. 7 crosses Dean Brook somewhere near here. Farther up stream, at L. 13 and 14 and again half a mile higher, the topmost beds are to be seen. The lowest beds of the group are well shown at L. 15, in a small tributary 350 yds. north-east of the Dean. At their

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base in this locality are bands with numerous gasteropods that are coated with a small incrusting bryozoon.

Upper Ludlow beds are exposed at several places around Willey Hall; but thence westward they are not well seen until Callaughton is reached. Here the higher part of the group is exposed in a series of road-cuttings, but the top is not seen except very obscurely at Callaughton Mill.

There is practically no variation in the fauna of the Upper Ludlow throughout the area; and there is no obvious difference between the fossil contents of the top and bottom portions of the group. The following is a list that may be taken as representative :—

Favosites ?
Serpulites longissimus *Murch.*
Atrypa reticularis (*Linn.*)
Camarotoechia nucula (*J. de C. Sow.*)
Chonetes minima (*J. de C. Sow.*)
Chonetes striatella (*Dalm.*)
Orbiculoidea rugata (*J. de C. Sow.*)
Orbiculoidea sp. nov.
Orthis (Dalmanella) elegantula *Dalm.*
,, ,, *cf.* lunata *J. de C. Sow.*
Cucullella ovata (*J. de C. Sow.*)
Modiolopsis ?
Orthonota amygdalina (*J. de C. Sow.*)
,, sp.
Pterinea *cf.* retroflexa *Wahl.*
,, sp.
Naticopsis *cf.* glaucinoides (*J. de C. Sow.*)
Orthoceras sp.

Temeside Group.—This division is well represented in the sections of Linley and Dean Brooks. Fig. 3 shows the detailed succession, and also indicates the portion of the sequence seen in each of the main exposures.

Ludlow Bone Bed.—The Ludlow Bone Bed is not well developed in the Wenlock area. There is everywhere a well-marked surface at which the prolific Upper Ludlow fauna of hinged brachiopods practically ceases, and above which sandy beds with numerous fish, plant, and eurypterid remains appear. In this sense the Ludlow Bone Bed horizon is definitely present, but it has not been seen as an actual layer of fish-fragments farther east than Callaughton.

In Dean Brook the horizon is obscurely exposed in two places about half a mile apart, one on each side of Darley. At the one above Darley (L. 16) a 4-in. sandy mudstone, separated from the top of the Upper Ludlow beds by 1 ft. 9 in. of olive to brown mudstone with *Beyrichia* and lamellibranchs, yielded *Serpulites longissimus* Murch., *Lingula sp.*, *Beyrichia kloedeni* M'Coy, *Ceratiocaris ?*, and *Onchus sp.* The one below Darley (L. 13 and 14) shows a similar section, viz., a band of chocolate-coloured sandstone about 6 in. thick at about 2 ft. above the Upper Ludlow. It contains *Pachytheca*, small *Lingulae*, gasteropods, *Beyrichia*, and fish-fragments, all poorly preserved. The beds between it and the Upper Ludlow show small, poorly preserved lamellibranchs.

Nothing is to be seen of this horizon between Dean Brook and Callaughton Mill; but at the latter place there is a much overgrown exposure in the stream-bed just below the weir. The top of the Upper Ludlow is very rotten, having had most of its calcium car-

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bonate removed by leaching, as is very frequently the case. Just above it there is a bone-bed about a quarter of an inch thick, in grey to olive sandy shale. The bone-bed is of the usual Ludlow type, with dermal studs of *Thelodus parvidens* Ag., fragments of other fish and of brachiopods, phosphatic concretions, and *Murchisonia ?*.

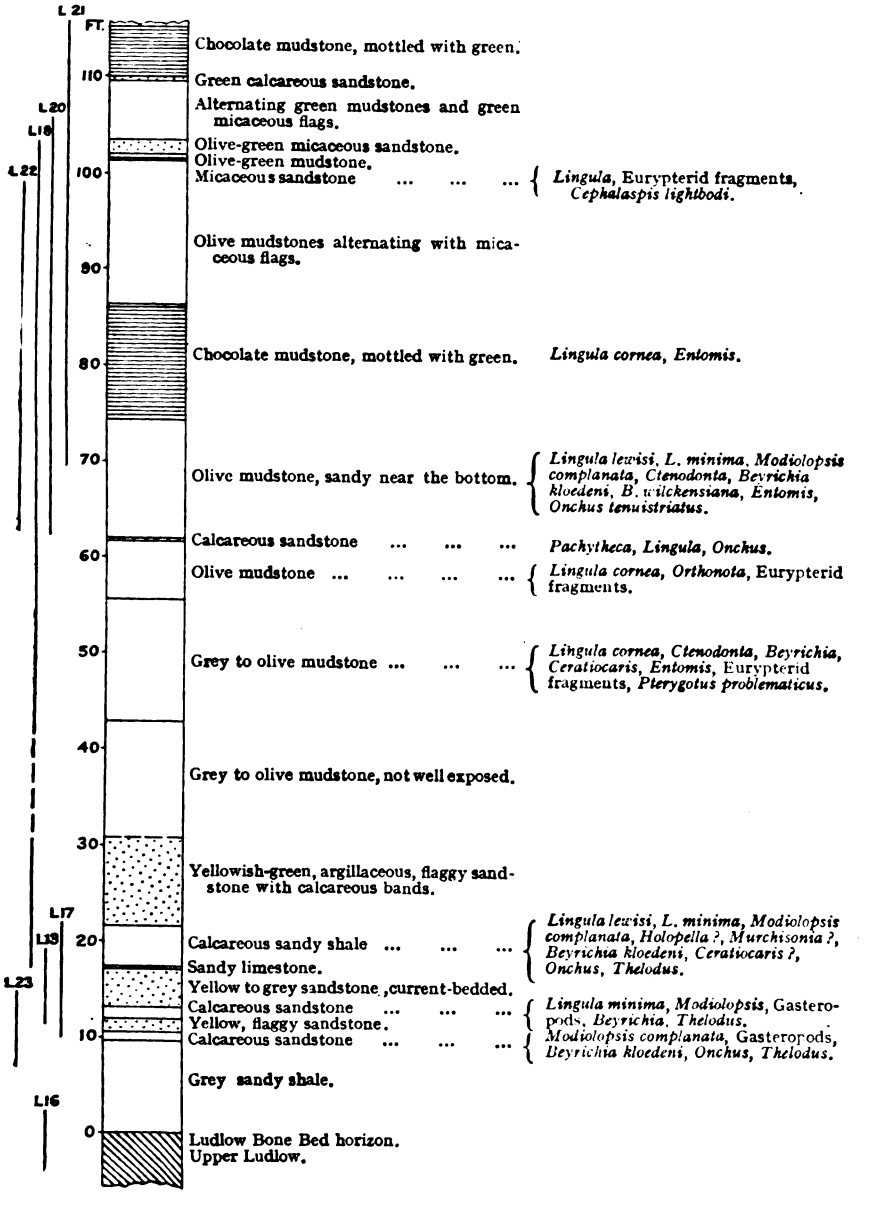
L 21
FT.
110
L20
L19
L22
100
90
80
70
60
50
40
30
L17
L18
20
L23
10
L16
0
Chocolate mudstone, mottled with green.
Green calcareous sandstone.
Alternating green mudstones and green micaceous flags.
Olive-green micaceous sandstone.
Olive-green mudstone.
Micaceous sandstone ... ... { Lingula, Eurypterid fragments, Cephalaspis lightbodi.
Olive mudstones alternating with micaceous flags.
Chocolate mudstone, mottled with green. Lingula cornea, Entomis.
Olive mudstone, sandy near the bottom. { Lingula lewisi, L. minima, Modiolopsis complanata, Ctenodonta, Beyrichia kloedeni, B. wilckensiana, Entomis, Onchus tenuistriatus.
Calcareous sandstone ... ... Pachytheca, Lingula, Onchus.
Olive mudstone ... ... { Lingula cornea, Orthonota, Eurypterid fragments.
Grey to olive mudstone ... ... { Lingula cornea, Ctenodonta, Beyrichia, Ceratiocaris, Entomis, Eurypterid fragments, Pterygotus problematicus.
Grey to olive mudstone, not well exposed.
Yellowish-green, argillaceous, flaggy sandstone with calcareous bands.
Calcareous sandy shale ... ... { Lingula lewisi, L. minima, Modiolopsis complanata, Holopella ?, Murchisonia ?, Beyrichia kloedeni, Ceratiocaris ?, Onchus, Thelodus.
Sandy limestone.
Yellow to grey sandstone, current-bedded.
Calcareous sandstone ... ... { Lingula minima, Modiolopsis, Gasteropods, Beyrichia, Thelodus.
Yellow, flaggy sandstone.
Calcareous sandstone ... ... { Modiolopsis complanata, Gasteropods, Beyrichia kloedeni, Onchus, Thelodus.
Grey sandy shale.
Ludlow Bone Bed horizon.
Upper Ludlow.

FIG. 3.—*Generalized section of Downtonian strata in the Linley and Dean Brooks.*

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As will be noted later, the Ludlow Bone Bed develops rapidly to the south-west of this point.

Downton Castle Sandstone and Temeside Shales.—The best sections of these beds are to be seen in the valley of Linley Brook. They are exposed at intervals for about a mile down stream from Linley Bridge. The stream has not at any place cut down to the Ludlow Bone Bed horizon, but in places must be within a few feet of it. Just above Linley Bridge, in the fork between the Broseley and Willey roads, the stream-bed shows sandy limestone-bands with *Modiolopsis complanata* and fish-remains. In the old sunken road leading down to the brook from Linley Hall (L. 17) the sandstone portion of the sequence is well exposed. The section is as follows :—

	Ft.	In.
Sandy shale, calcareous, with *Lingula lewisi* J. de C. Sow. ... ... over	4	0
Calcareous band, impersistent	–	3
Yellow sandstone	4	0
Limestone with *Lingula minima* J. de C. Sow., *Modiolopsis ?*, *Beyrichia sp.*, and gasteropods	–	9
Yellow sandstone ... ... 1 to	2	0
Calcareous bands with *Lingula sp.*, *Modiolopsis* cf. *complanata* (J. de C. Sow.), *Orthonota ?*, poorly preserved gasteropods, *Beyrichia kloedeni* M'Coy, and *Onchus sp.* ...	1	0

About 330 yds. farther down stream most of the beds of the Temeside Group are exposed in the steep sides of a rill on the right bank of the brook (L. 18). The details are as follows :—

	Ft.	In.
Grey shales and grey-green micaceous flags, alternating; succeeded, probably within 10 to 20 ft., by chocolate mudstones	–	–
Micaceous sandstones and grey-olive mudstones, with plant-fragments, *Lingula sp.*, eurypterid fragments, and *Cephalaspis lightbodyi* Lank.	–	2 to 3
Micaceous flags with fish and *Lingula* fragments, alternating with mudstones ... ... 15 to	20	0
Chocolate mudstone, mottled with green, and containing *Lingula* cf. *cornea* J. de C. Sow. and *Entomis sp.*... 10 to	12	0
Olive mudstones with *Ctenodonta ?*, *Beyrichia kloedeni* M'Coy, *B. wilckensiana* Jones, and *Entomis sp.*... 10 to	12	0
Calcareous sandstone with *Pachytheca ?*, *Lingula sp.*, and *Onchus sp.*	–	2
Olive mudstone with *Lingula* cf. *cornea* J. de C. Sow., *Orthonota ?*, and eurypterid fragments	6	0
Grey to olive mudstone with *Lingula cornea* J. de C. Sow., *Ctenodonta sp.*, *Beyrichia sp.*, *Ceratiocaris ?*, *Entomis sp.*, eurypterid fragments, and *Pterygotus* cf. *problematicus* Salter ... ... 12 to	15	0
Gap ... ... 12 to	15	0
Yellowish-green sandstone, flaggy in parts, with calcareous bands ... ... 8 to	10	0
Calcareous sandy shales with *Lingula lewisi* J. de C. Sow., *L.* cf. *minima* J. de C. Sow., *Modiolopsis complanata* (J. de C. Sow.), *Holopella ?*, *Murchisonia ?*, *Beyrichia kloedeni* M'Coy, *Ceratiocaris ?*, *Onchus sp.* ... ... 6 to	8	0

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These lowest sandstones and calcareous beds are also seen for about a quarter of a mile down stream from this point. The calcareous bands are impersistent. At L. 19 they yielded *Platyschisma ?*. This is the only trace as yet noted of *Platyschisma* from these beds in the Wenlock district.

Farther down stream we rise in the sequence, and the following succession is seen in a rill-course just south-east of Hollybush Farm (L. 20) :—

	Ft.	In.
Olive mudstone and micaceous greenish-brown flags, alternating, with fragments of *Lingula* and *Ceratiocaris ?* ... ... about	10	0
Olive mudstone with ? eurypterid fragments	2	0
Gap ... ... about	20	0
Olive mudstone with *Beyrichia*, and ? fish-fragments	6 to 10	0
Chocolate-coloured mudstone	6 to 10	0
Olive mudstone with a hard band containing indeterminable fish and shell fragments	2 to 3	0
Calcareous sandstone	–	3
Olive mudstone, getting sandy towards the bottom, and containing a few entomostraca, etc.	12 to 16	0

About 30 ft. of beds in the same part of the sequence are shown on the opposite side of the valley, 300 yds. south of Hem (L. 22). Another exposure (this is probably the one in which Roberts and Randall saw the higher part of their section) is to be seen in the tributary stream flowing through Nicholl's Coppice. Here (L. 21) the junction of the Temeside and Ledbury groups is exposed. The section is as follows :—

	Ft.	In.
Ledbury Group : chocolate mudstone mottled with green	–	–
Temeside Group :—		
Green calcareous sandstone with plant-remains near the bottom	–	6
Green mudstones and green micaceous flags alternating ... ... about	6	0
Olive-green micaceous sandstone	1	6
Olive-green mudstone	–	6
Green flags and sandy mudstone	2	6
Olive-green mudstone	15	0
Chocolate mudstone mottled with green	12	0
Olive-green mudstone with *Lingula lewisi ?* J. de C. Sow., *L. minima* J. de C. Sow., *Modiolopsis ?*, *Beyrichia kloedeni* M'Coy, *B. wilckensiana* Jones, *Entomis sp.*, *Ceratiocaris ?*, and *Onchus tenuistriatus* Ag. ... ... over	5	0

In Dean Brook only the lower portion of the Temeside Group is present, as the higher beds are cut out by the unconformity at the base of the Coal Measures. The beds in question are exposed in the banks of the brook at Darley, and thence for about half a mile down stream. At L. 13 the Downton Castle Sandstone shows the following section :—

	Ft.
Grey to yellow current-bedded sandstone, with hard calcareous bands containing gasteropods and small lamellibranchs ... ... about	10

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	Ft.
Sandy limestone with *Pachytheca*, fragments of *Lingula*, *Modiolopsis complanata* (J. de C. Sow.), fragments of gasteropods, *Beyrichia kloedeni* M'Coy, *Onchus sp.*, and *Thelodus sp.* ...	2
Mudstone partly; not well exposed	6
Dark micaceous sandstone with ? fish-remains ... about	1

The base of this section is probably 5 to 10 ft. above the Ludlow Bone Bed. A portion of the sequence in approximately the same position is shown below a small waterfall some 200 yds. higher up the stream (L. 23). Here we have the following :—

	Ft.	In.
Flaggy sandstone ... ... over	2	0
Limestone with *Lingula*, *Modiolopsis*, *Beyrichia*, fish-fragments, etc.	2	0
Flaggy yellow sandstone ... ... about	2	0
Limestone with *Modiolopsis*	–	9
Calcareous bone-bed	–	2
Sandy shales ... ... 2 to	3	0

Below this section 8 to 10 ft. of sandy shales are exposed and probably represent most of the sequence between it and the Ludlow Bone Bed. The beds of the Temeside Group are exposed at intervals between here and L. 16, but have not yielded much additional information.

On the north-western limb of the Willey and Dean anticline some beds in the Downton Castle Sandstone portion of the sequence are exposed in a tributary of the Dean Brook 600 yds. west-north-west of the Dean. They lie beneath the basal conglomerate of the Coal Measures, and consist of 5 ft. of sandy mudstones with *Beyrichia* over a sandy calcareous band with fish-remains. The Temeside beds also crop out in Willey Park at the south-west end of the anticline, but are very poorly exposed. The weir at the Middle Pool shows 5 to 6 ft. of sandy mudstones alternating with chocolate to grey micaceous flags, overlying 6 ft. of olive mudstone with dark nodular concretions.

The next exposure of these beds is 250 yds. east-south-east of Wenlock Walton, where the old sunken road is cut in beds lying probably between 80 and 90 ft. above the Ludlow Bone Bed. It shows about 1 ft. of speckled grey sandstone, probably originally calcareous, with grey mudstone above and red mudstone below. The sandstone yielded *Lingula lewisi* J. de C. Sow. and *Onchus sp.* As noted by Prestwich, the lowest part of the Old Red Sandstone is exposed at Callaughton, but the exposures are now mostly covered over. The Downton Castle Sandstone is worked for local use in a quarry 120 yds. south-west of Callaughton Mill. The section shows 4 ft. of very thinly-bedded micaceous sandstone, over 3 ft. of thickly-bedded greyish-yellow speckled sandstone with carbonaceous layers. This is underlain by 3½ ft. of flaggy sandstone with layers of shale, associated with much carbonized matter and some fragments of *Lingula*. Below this there is a bed 4 ft. thick of solid sandstone similar to that above. Other portions of the sequence not accurately placed are to be seen in the road between Callaughton Mill and

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Callaughton House. They yield badly preserved remains of *Lingula*, lamellibranchs, and fishes. In general appearance they are similar to the Linley Brook rocks.

Ledbury Group.—The predominantly red beds that immediately succeed the Temeside Shales cover most of the ground south of Linley and Shirlett. The rocks are chiefly mudstones; but several persistent sandstone-bands form distinct features throughout the ground between Linley and Atterley. The lowest is a micaceous sandy cornstone, about 2 ft. thick and some 150 ft. above the Ludlow Bone Bed. It has been seen only in the tributary of Linley Brook running through Nicholl's Coppice. It seems likely, however, that a flaggy micaceous sandstone about 3 ft. thick, which is exposed in the banks of Walton Brook, half a mile south-east of Walton Grange and half a mile due west of Atterley, is near the same horizon. It yields the following forms:—*Lingula cornea* J. de C. Sow., *Beyrichia kloedeni* M'Coy, *B. wilckensiana* Jones, *Leperditia* cf. *elongata* Weller, *Thelodus sp.*, and *Onchus sp.* The *Lingulae* and ostracods are very abundant in places. About 20 ft. above the bed seen in Nicholl's Coppice a greenish calcareous sandstone 2 to 3 ft. in thickness is visible. A bed in approximately the same position is exposed in the road just south of Atterley and shows 5 ft. of current-bedded sandstone, red to purple and mottled with grey and green. Apparently at its base is a calcareous band with fish-fragments.

A band some 35 ft. above the last and about 200 ft. above the Ludlow Bone Bed is the most conspicuous of all; and it forms the main feature in the topography of the Old Red Sandstone area. It is especially well seen on both sides of Shirlett Hill, where it caps a prominent ridge. From the imperfect exposures available it appears to be a greenish flaggy micaceous sandstone spotted with black. In parts it is calcareous, but has not as yet yielded any definite fish-remains. A bed of sandstone about 60 ft. higher in the sequence is conspicuous round the south end of Shirlett Hill, but is not satisfactorily exposed. It seems to be micaceous, and in places is calcareous.

3. The Country between Wenlock and Ludlow

The Siluro-Devonian rocks of Corvedale have not been mapped in detail; but certain points of value in a comparison of the two districts have been ascertained. Fig. 4 shows the localities referred to below, and also the outcrop of the Ludlow Bone Bed. The Upper Ludlow beds are exposed at frequent intervals throughout, and have been, in many places, quarried for local building-stone. The road-cuttings in some places expose the top of the Upper Ludlow and the Ludlow Bone Bed. Otherwise in this valley the Temeside Group is almost entirely concealed. Consequently it is impossible to map the top of the group with anything approaching accuracy.

Between Callaughton and Bourton there is nothing of importance. A quarry just north-west of the cross-roads at Bourton shows the

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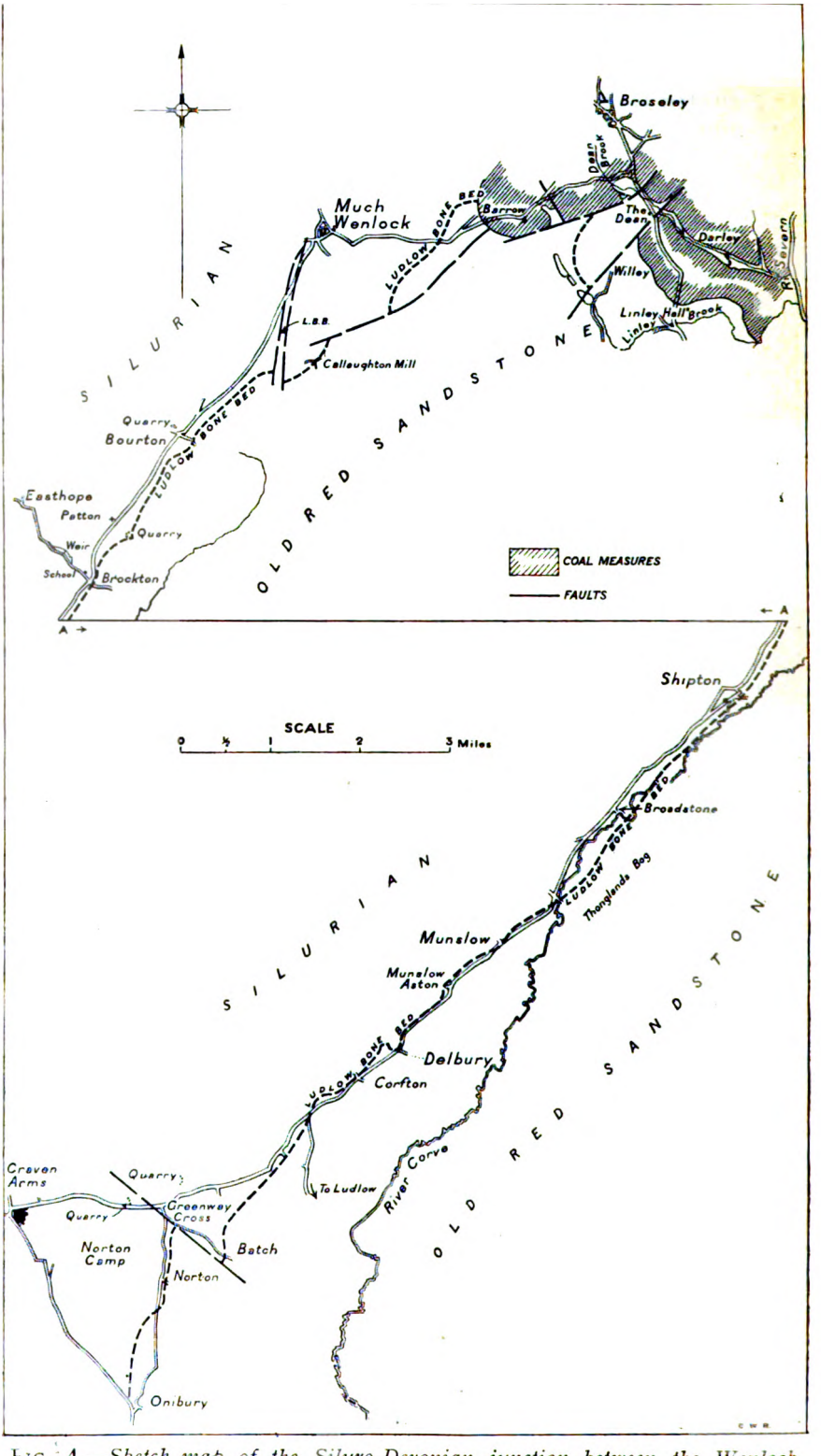

FIG. 4.—*Sketch map of the Siluro-Devonian junction between the Wenlock and Ludlow Districts.*

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top of the Aymestry Group. The usual development of *Atrypa reticularis* and *Wilsonia wilsoni* is present, and there are some specimens of *Dayia navicula*. The weathering is cellular, as at Ludlow. The position of the section with reference to the Downton Castle Sandstone precludes a greater thickness than 100 ft. for the Upper Ludlow.

An old quarry beside some cottages just south-east of Patton shows the highest 30 ft. of the Upper Ludlow beds. They are highly fossiliferous, containing *Camarotoechia nucula* (J. de C. Sow.), *Chonetes striatella* Dalm., *Orthis* (*Dalmanella*) *lunata* J. de C. Sow., *O.* (*Dalmanella*) *sp.*, *Cornulites serpularius* Schloth., *Stenopora sp.*, *Arabellites anglicus* Hinde, *Oenonites aspersus* Hinde, and *Thelodus sp.* The highest beds are not so fossiliferous. The Ludlow Bone Bed horizon is exposed at the top, and just below it there occur the following forms :—

Delthyris elevata (*Dalm.*)
,, sp.
Orbiculoidea rugata (*J. de C. Sow.*)
Small orthids
Pterinea squamosa *M'Coy*
Pterinea sp.
Beyrichia sp.
Tentaculites ?
Eurypterus ?
Onchus sp.

The exposure of the Bone Bed is a poor one, with only phosphatic concretions and scant fragments of fish. There is a sudden change at that horizon from the grey calcareous flags of the Upper Ludlow to fine-bedded olive mudstones, of which 4 to 5 ft. are seen, containing *Pachytheca* near the bottom and fragments of eurypterids above.

At Brockton nearly all the beds from the lower portion of the Aymestry Group to the Ludlow Bone Bed can be seen. At the weir half a mile from Brockton on the Easthope road, beds fairly low in the Aymestry Group contain large specimens of *Atrypa reticularis*, strophomenids, small orthids, *Lingula*, and crinoid ossicles. Thence to Brockton the stream-section shows in succession the middle portion of the Aymestry with *Sieberella galeata*, the higher beds with *Wilsonia wilsoni* and its associates (including a few specimens of *Dayia navicula*), and the passage upwards into the Upper Ludlow Group by the increasing abundance of *Camarotoechia nucula* and *Chonetes striatella*. The thickness of the Aymestry Group is about the same as at Wenlock, namely 80 to 100 ft. The Upper Ludlow Beds are well shown in a quarry just behind the school. They are distinctly flaggy and have been worked for building-stone. *Serpulites longissimus* is abundant in them. The total thickness of the group is about 100 ft. The highest beds are to be seen in the road-cutting just north of the village ; and in the entrance to the farmyard about 150 yds. north of the cross-roads the Ludlow Bone Bed is admirably exposed. It is in two layers about 6 in. apart. The lower is about a quarter of an inch thick and is not very persistent. Immediately below it occur *Pterinea retroflexa ?*, *Orthoceras sp.*, *Spirorbis* and *Beyrichia*, along with the usual Upper Ludlow fossils. Above it are 6 in. of sandy mudstone with *Modiolopsis* and small smooth gasteropods like those in the bone-bed at Callaughton Mill. Then

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follows the main portion of the bone-bed, consisting of two quarter-inch bands about an inch apart, full of the characteristic fish and other fragments, including *Orbiculoidea rugata ?* in abundance. Above it are some 6 ft. of nearly barren olive-coloured sandy mudstones with thin bands of sandstone.

At Shipton[1] the Ludlow Bone Bed is exposed about 200 yds. south-east of the church, in a lane connecting the old and new roads. The section shows 6 to 8 ft. of yellowish-brown, flaggy to massive sandstone, with *Lingula minima*, *Modiolopsis complanata* and small gasteropods; the bottom foot or so is more finely bedded. It rests on the Bone Bed which is about 2 in. thick, is soft and friable, and contains *Lingula sp.*, *? Platyschisma helicites* (J. de C. Sow.), *Onchus ?*, and *Thelodus sp.* Below it lie 2 ft. of greyish-brown fine-bedded flags, with lamellibranch and ? eurypterid fragments. Then come normal Upper Ludlow flags. This is the farthest point up Corvedale at which *Platyschisma helicites* (or a species exceedingly like it) has been definitely recorded, and it occurs in the Ludlow Bone Bed.

In the lane on the opposite side of the main road from the above section, Upper Ludlow beds are again exposed, owing either to slight faulting or to a roll.

For the next three miles along the Ludlow road the Upper Ludlow beds are exposed at intervals, and vary little in character and thickness. On the east of the Corve at Broadstone the Downton Castle Sandstone forms a feature, but this is not a common occurrence. A few isolated exposures of the Temeside Shales can be seen on the high ground between Broadstone and Thonglands Bog.

Proceeding southward we find the Ludlow Bone Bed under an oak, on the west side of the main road, about a quarter of a mile north of Munslow. The section shows 3 to 4 ft. of thinly-bedded greyish-green flags with carbonaceous markings and containing *Lingula cornea* J. de C. Sow., *Modiolopsis sp.*, other indeterminate lamellibranchs, and *Holopella ?*. Below this is the Bone Bed, about an inch thick, with *Onchus sp.* and *Thelodus sp.* It is unusually full of phosphatic concretions. Below it are exposed 2 ft. of flags, similar to those first mentioned, with scant specimens of *Lingula*, *Chonetes*, *Pterinea*, etc.

Between Munslow and Munslow Aston the road passes for some distance over the Temeside Shales and there are some exposures of alternating grey and chocolate-coloured sandy mudstones. At Munslow Aston, opposite the inn, there is an excellent section that might repay further investigation. It shows 2 ft. of the base of the Downton Castle Sandstone over 4 ft. of sandy shales, with a band about a foot from the base containing *Modiolopsis complanata* and small smooth gasteropods like those already mentioned at Brockton. Underneath these shales is the Ludlow Bone Bed, about half an inch thick. It rests on typical Upper Ludlow beds, seen to 6 ft., and

[1] See also L. D. Stamp, *Geol. Mag.*, 1923, p. 369.

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containing the usual characteristic fossils, including *Delthyris elevata* (Dalm.).

The next section is just south of Delbury, on the west side of the road, where the Downton Castle Sandstone is quarried and is exposed to a thickness of about 15 ft. It is massive in the middle, but very flaggy above and below. In places it shows beds with abundant specimens of *Modiolopsis complanata* (J. de C. Sow.) and *Platyschisma helicites* (J. de C. Sow.).

The road from Delbury to Middlehope shows the Upper Ludlow and Aymestry beds. They still maintain the characters they have farther north, and are each about 100 ft. thick. There is no faunal distinction between top and bottom of the Upper Ludlow, nor is there any development of distinct zones of *Dayia navicula* or of *Conchidium knighti*. The Aymestry beds, however, gradually become more calcareous southward, and from this point onward have been quarried in places.

Half a mile south-west of Delbury the Ludlow Bone Bed is again exposed, this time in a farm-track at a point some 50 yds. west of the main road. Here it is highly calcareous and about an inch thick, with subsidiary calcareous bands in the succeeding 6 inches. It is overlain by 6 ft. or more of thinly-bedded flags with *Lingula minima*, and lies directly on Upper Ludlow beds with the usual fauna. The Downton Castle Sandstone is exposed in the village of Corfton.

At the junction of the roads from Craven Arms and Ludlow the top 10 ft. of the Downton Castle Sandstone is exposed in a quarry. Above it are thinly-bedded greenish sandy shales, shown to a thickness of 4 or 5 ft. and containing *Beyrichia kloedeni* M'Coy and *Leperditia* cf. *elongata* Weller. There are further exposures both of Upper Ludlow and of Downton Castle Sandstone within the following half mile along the road to Craven Arms.

Portions of the Aymestry Group are well exposed in two quarries between this and Craven Arms. Even here we find that the principal and indeed almost the only fossil is a large type of *Atrypa reticularis*. No *Conchidium knighti* is to be seen. At the top of the Aymestry beds appear *Wilsonia wilsoni* and *Camarotoechia nucula*, whilst *Dayia navicula* is quite rare. Indeed, from this point to Wenlock it can be said that *Conchidium knighti* has not yet been recorded, and that the *Dayia navicula* zone is almost non-existent.

Exposures on the road from Greenway Cross to Batch show the Upper Ludlow beds immediately north of the Norton area. Here *Camarotoechia nucula* is somewhat predominant towards their base and *Chonetes striatella* towards their summit. The Ludlow Bone Bed was not seen near Batch ; but on the crest of the hill a quarter of a mile to the east the Downton Castle Sandstone is exposed, with *Lingula minima* and *Modiolopsis complanata*.

4. Comparison of the Successions at Wenlock and Ludlow

Description of the highest Silurian rocks of Wenlock is not complete without comparison with the succession at Ludlow as

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established by G. L. Elles and I. L. Slater.[1] This is best done group by group.

Aymestry Group.—This has a surprisingly constant thickness of about 80 to 100 ft. from Linley and Willey right down Corvedale to within a mile or so of Norton Camp. *Conchidium knighti* has not been found in any locality north of Norton Camp, at which place it is recorded as being present, although not common.[2] It is abundant at View Edge and farther south, in certain bands, but not usually throughout the limestone. The most common fossil in the group throughout the Wenlock area is a large form of *Atrypa reticularis*, and with it in the middle beds *Sieberella galeata* is almost invariably present. The top 30 or 40 ft. of the group show bands with abundance of *Wilsonia wilsoni*, accompanied by *Camarotoechia nucula*, *Chonetes striatella* and *Orthis lunata*; but *Dayia navicula* is rare, though the specimens of it that have been found were in these beds.

Upper Ludlow Group.—Throughout the Wenlock district, and as far south as Norton Camp, these beds maintain a thickness of about 100 ft. The characteristic fossils are identical with those at Ludlow. There are local variations in their relative distribution within the group, e.g., a greater development of lamellibranchs in the lower portion in Dean Brook, a strong development of *Chonetes striatella* at the base near the Dean, and abundance of *Serpulites longissimus* in the middle beds at Brockton. There is a predominance of *Camarotoechia nucula* at the base and of *Chonetes striatella* at the summit near Batch; but in the exposures north-east of the road from Craven Arms to Onibury *Camarotoechia nucula* is plentiful throughout the higher portion. In the Whitcliffe section also any subdivision of the Upper Ludlow, apart from the transitional topmost band with *Delthyris elevata*, is difficult to uphold in face of abundant *Chonetes striatella* near the base and the presence of *Camarotoechia nucula* throughout. Direct measurement of the group is possible at this locality,[3] and proves the thickness of the strata between the top of the Dayia shales and the Ludlow Bone Bed to be 130 to 140 ft., the 'concretion band' of Elles and Slater being about 50 ft. from the base. This is much less than previous estimates, but agrees well with the evidence in the Wenlock district.

Poverty of sections makes it impossible to say much about the highest portion of the Upper Ludlow Group—corresponding to the 'Spirifera elevata' beds of Elles and Slater. In Dean Brook and at Callaughton they are virtually absent, as the fish-remains appear immediately above beds full of *Camarotoechia* and *Chonetes*. At Patton the top foot or so shows *Delthyris elevata* with *Pterinea sp.* etc.; and there is a distinct band with small brachiopods and large

[1] 'The Highest Silurian Rocks of the Ludlow District,' *Quart. Journ. Geol. Soc.*, vol. lxii, 1906, p. 195.

[2] Murchison, R. I., 'The Silurian System,' 4to, London, 1839, pp. 202–3.

[3] Lightbody, R., *Quart. Journ. Geol. Soc.*, vol. xix, 1863, pp. 368–71, postulates two faults crossing the section, but later work discounts the evidence for them.

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Pterinea-like lamellibranchs below the Ludlow Bone Bed at most localities farther south.

Temeside Group.—The descriptions given above are sufficient to show that the Ludlow Bone Bed exists as a bone-bed throughout Corvedale, and that the horizon can be identified with accuracy in the Linley area. It may be noted that *Platyschisma helicites* occurs in it at Delbury. The same species was found in the Ludlow Bone Bed at two localities, during a recent visit to Ludlow. The first of these is at the cottage by the old mill-race weir north-west of Forge Bridge. Here the exposure, as described by Elles and Slater, shows the *Platyschisma* bed as a bone-bed (the Downton Bone Bed) some 3 ft. above the Ludlow Bone Bed. The latter also contains *P. helicites*. The other exposure is at the track-junction a quarter of a mile south-west of Lower Deepwood Farm (on the map accompanying Elles and Slater's paper), where again both horizons are displayed and both yield *P. helicites*. The top of the Upper Ludlow beds is also to be seen on the road to Ludlow, half a mile west of the point (at Lower Deepwood Farm) at which it is shown running into the east-and-west fault mapped by them.

The beds of the Downton Castle Sandstone show notable similarity in the Ludlow and Wenlock areas. Immediately above the Ludlow Bone Bed there is in general a band of nearly barren sandy shales, with a thickness of 2 to 3 ft. at Ludlow and 8 to 10 ft. at Wenlock. Then follows a fairly definite calcareous horizon—the Downton Bone Bed—with *Modiolopsis complanata* and usually numerous gasteropods, accompanied by dermal studs of fish. It is characterized in the Ludlow district by *Platyschisma helicites*; but at Wenlock this fossil is rare. Then comes massive to flaggy sandstone, yellowish in colour, with *Lingula minima* and plant-remains. It contains calcareous bands with *Beyrichia*, brachiopods, and fish-remains at Ludlow, and these are still more common at Wenlock. The sandstone passes upwards into thin-bedded micaceous sandy beds with some fish-remains and fragments of *Lingula*. The total thickness of the Downton Castle Sandstone is some 30 ft. at Wenlock and 30 to 50 ft. at Ludlow.

The Temeside Shales also show similar features in the two areas. Grey to olive mudstones with bands containing the remains of fish, *Lingula* and eurypterids compose most of the succession, but chocolate mudstone mottled with green is present in subordinate amount. Too close a correspondence in detail is not to be expected; but they have about the same thickness in each district, namely 90 to 120 ft. They show *Lingula cornea* throughout, a 'fragment-bed' at the top and a bone-bed (the Temeside Bone Bed) some 10 ft. below it (4 or 5 ft. below it opposite Ludlow Sewage Works).

To sum up, the Ludlow succession is practically complete at Wenlock, though somewhat thinner than at Ludlow, especially in the calcareous Aymestry Group.

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APPENDIX II

On the Upper Limestone Group and 'Millstone Grit' of North East Cumberland

By F. M. Trotter, M.Sc., and S. E. Hollingworth, M.A., B.Sc.

Text-figure 1.

Introduction.—The sequence of beds from the Great Limestone to the base of the Coal Measures here described lies on the borders of Cumberland and South Northumberland and falls within the confines of the Brampton Sheet (New Series 18). The area is difficult to interpret on account of a thick blanket of boulder-clay on the lower ground and the widespread occurrence of hill peat on the fells. The obscurity thus produced is accentuated by faulting. The principal feature is the Stublick Fault of Caledonian trend with a maximum downthrow to the north of 1,500 ft. It may be noted that the calculation of this throw is one result of the establishment of the sequence.

No memoir upon the area was written after the primary survey, and the true sequence was then not established. The Alston sequence of Westgarth Forster[1], 600 ft. less than that now proved, was imposed on the one-inch Sheet (published in 1890) by the introduction of a number of hypothetical faults. Thus a supposedly important fault occupied by a whin dyke, trending E.15°N., has now been proved to be non-existent, both in underground workings of the Little Limestone Coal, and at the surface, in the South Tyne, near Wydon.

The generalised sequence is shown in Fig. 1, together with a series of sections illustrating the persistence of the marine horizons and the coals. A well-defined rhythm characterises the deposition of the Upper Limestone Group. This rhythmic succession is the result of repeated levelling up of an intermittently subsiding delta, *viz.*, shale, sandstone and coal in upward succession, followed by a marine transgression represented by a limestone or calcareous sandstone. Thus coals and calcareous bands are intimately associated, but either may be absent locally, as for example, the Lower Oakwood Limestone in the Denton Fell boring. This association is of considerable importance in correlation, particularly in the interpretation of boring records, and the term 'coal-calcareous horizon' is suggested for it.

With the exception of a few corals named by Dr. S. Smith all the fossils have been determined by Mr. J. Pringle.

[1] Forster, Westgarth, 'A Treatise on a Section of the Strata from Newcastle-on-Tyne to the Mountain of Cross Fell in Cumberland, with Remarks on Mineral Veins in General,' 1821.

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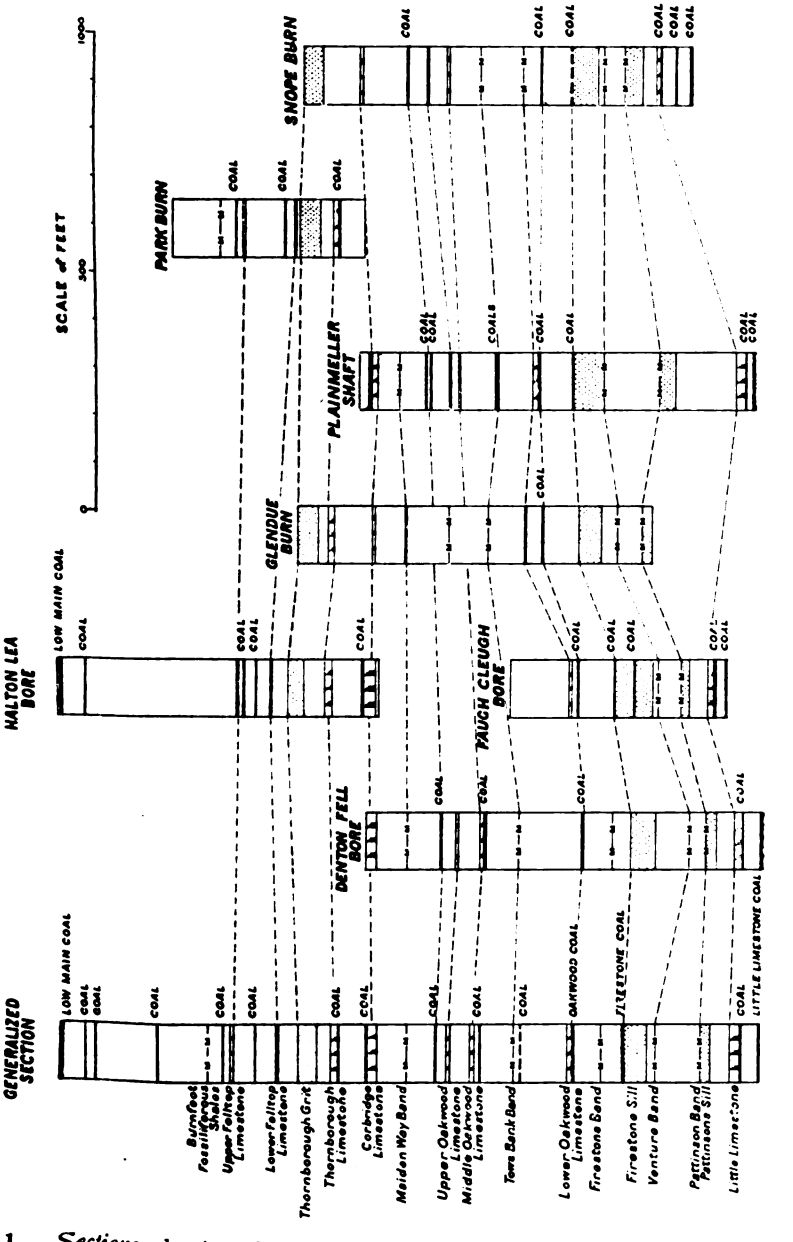

FIG. 1.—*Sections showing the persistence of Marine and Coal Horizons in North-East Cumberland.*

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Sequence.—The Great Limestone, which is the most persistent bed within the Carboniferous of the North of England, can usually be divided lithologically into two :—the ' main posts,' two massive blue grey limestones each 9 to 10 ft. in thickness, and the overlying ' tumbler ' beds, 20 to 30 ft. of alternations of limestone and calcareous shale. The Great Limestone yields a characteristic faunal assemblage.

Fauna.—Saccammina carteri Brady, *Aulophyllum fungites* (Flem.), mut. *pachyendothecum* S. Smith, *Caninia* ?, *Carcinophyllum sp.*, *Dibunophyllum* cf. *muirheadi* Nich. and Thoms., *D. turbinatum* (M'Coy), *Zaphrentis* cf. *constricta* R. Carr., *Fenestella sp.*, *Athyris roissyi* (L'Eveillé), *Buxtonia scabricula* ? (Mart.), *Chonetes* cf. *hardrensis* Phill., *Leptaena analoga* (Phill.), *Lingula sp.*, *Productus costatus* J. de C. Sow., *P.* cf. *edelburgensis* Phill., *P. sp. nov.*, *P. sp.* (' *latissimus* '-group), *P.* cf. *longispinus* J. Sow., *P. margaritaceus* Phill., *P.* cf. *pugilis* Phill., *Pustula punctata* (Mart.), *Rhipidomella michelini* (L'Eveillé), cf. *Schellwienella crenistria* (Phill.), *Schuchertella radialis* (Phill.), *Spirifer calcaratus* M'Coy, *S. sp.* (' *bisulcatus* '-group), *S. trigonalis* (Mart.), *Allorisma sulcata* (Flem.), *Euomphalus sp.*, *Euphemus urei* (Flem.).

The Great Limestone is succeeded by a thick bed of shale, the ' Great Shale,' 90 ft. thick in the north, but reduced to 20 ft. in the south. This shale is unfossiliferous except near the base where obscure lamellibranchs have been found. A sandstone of variable thickness overlies the shale and is usually succeeded by the Snope Burn Band, a limestone 2 to 4 ft. thick with crinoidal remains.

The Snope Burn band is followed by the ' Coal Sills,' a series of sandstones and shales attaining a thickness of 60 ft. and including the Little Limestone coals. When it forms one seam the Little Limestone Coal is 6 ft. thick and immediately underlies the Little Limestone. The coal, however, frequently splits into two, three, or four seams.

The Little Limestone varies greatly in thickness, its extremes being 50 ft. near Greenhead and 6 ft. in Croglin Water.

Fauna.—Emmonsia parasitica (Phill.), *Diphyphyllum lateseptatum* (M'Coy), *Zaphrentis* cf. *constricta* R. Carr., *Fenestella sp.*, *Athyris expansa* (Phill.), *A.* cf. *lamellosa* (L'Eveillé), *Avonia youngianus* (Dav.), *Chonetes* cf. *hardrensis* (Phill.), *Composita ambigua* (J. Sow.), *Martinia glabra* (Mart.), *Productus concinnus* J. Sow., *P. costatus* J. de C. Sow., *P.* cf. *longispinus* J. Sow., *P. martini* J. Sow., *Pustula elegans* M'Coy, *P.* cf. *punctata* (Mart.), *Reticularia lineata* (Mart.), cf. *Schellwienella crenistria* (Phill.), *Spirifer* cf. *bisulcatus* J. de C. Sow., *S.* cf. *trigonalis* (Mart.), *Allorisma sulcata* (Flem.), *Ctenodonta undulata* (Phill.), *Leiopteria sp.* (? undescribed), *Limatulina scotica* Hind, *Nucula sp.*, *Protoschizodus axiniformis* (Portl.), *Sanguinolites variabilis* M'Coy, *Orthoceras sp.*

The Pattinson Band[1] forms the top of the sandstone of that name. It is also recorded from the Derwent Lead Mines 20 miles farther east.

Fauna.—Platycrinus sp., *Productus longispinus* J. Sow., *P. martini* J. Sow., *Schellwienella rotundata* I. Thomas, *Spirifer* cf. *bisulcatus* J. de C. Sow., *S. triangularis* (Mart.), *Actinopteria persulcata* (M'Coy), *Nucula luciniformis* Phill., *Bellerophon sp.*

[1] The marine horizons are indicated in Fig. 1 —M—M—.

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Between the Pattinson Band and the Firestone Sill several impure sandy limestones with fossiliferous shales are present These are combined in the sections (Fig. 1) as the Venture Band, which as a group is persistent.

Fauna.—Poteriocrinus ?, Avonia youngianus (Dav.), *Buxtonia scabricula* (Mart.), *Derbya ?, Productus* cf. *longispinus* J. Sow., *P. martini* J. Sow., *Schellwienella arachnoidea* (Phill.), *S.* cf. *crenistria* (Phill.), *S.* cf. *rotundata* I. Thomas, *Spirifer sp.* (' *bisulcatus* '-group), *S.* cf. *bisulcatus* J. de C. Sow., *S. trigonalis* (Mart.), *Actinopteria persulcata* (M'Coy), *Aviculopecten sp., Myalina flemingi* (M'Coy), *Pinna flabelliformis* (Mart.), *Protoschizodus subaequalis* de Kon., *Orthoceras sp., Phillipsia* cf. *eichwaldi* (Fischer de Wald.).

The Firestone Sill of Alston Moor was mapped in the course of the original survey. It is usually a coarse false-bedded, highly felspathic, grit and is invariably followed by a coal-calcareous horizon—the Firestone Band. The coal has been used for lime-burning in the Alston Moor district.

Fauna.—Buxtonia scabricula (Mart.), *Orbiculoidea nitida ?* (Phill.), *Productus sp. nov., P.* cf. *longispinus* J. Sow., *Pugnax pleurodon* (Phill.), *Schellwienella* cf. *rotundata* I. Thomas, *Streblopteria ornata* (R. Eth. jun.), *Aviculopecten dissimilis* (Flem.), *Nucula* cf. *gibbosa* (Flem.), *Entalis sp., Bellerophon sp., Phillipsia sp.*

Next in order is the Lower Oakwood coal-calcareous horizon, which lies some 300 to 360 ft. above the Little Limestone. The coal has a thickness of 2 ft. and has been worked locally. It may be correlated with the Oakwood Coal of the Tyne.

Fauna.—Buxtonia scabricula (Mart.), *Composita ambigua* (J. de C. Sow.), *Productus* cf. *edelburgensis* Phill., *P. latissimus* J. Sow., *P.* cf. *maximus* M'Coy, cf. *Schellwienella crenistria* (Phill.), *Spirifer trigonalis* (Mart.).

The Tows Bank Band is represented by coal or by limestone, but the association of these at any one locality has not been recorded.

Fauna.—Caninia sp., Dibunophyllum ?, Zaphrentis sp., Productus cf. *costatus* J. de C. Sow., *P. latissimus* J. Sow. The following forms have been collected from what we believe to represent the same horizon in New Water. *Solenopora* cf. *garwoodi* Hinde, *Buxtonia scabricula* (Mart.), *Orbiculoidea nitida* (Phill.), *Productus* cf. *corrugatus* M'Coy, *P. longispinus* J. Sow., *P. sp. nov. ?, Pugnax pleurodon ?* (Phill.), *Punctospirifer sp., Reticularia lineata* (Mart.), *Schellwienella* cf. *rotundata* I. Thomas, *Spirifer sp.* (' *bisulcatus* '-group), *Syringothyris cuspidata* (Mart.), mut. *cuspidata* North, *Pseudamusium anisotum ?* (Phill.), *Pterinopecten* cf. *pustulosus* Hind, *Sanguinolites striatus* Hind, *Orthoceras sp.*

The Middle Oakwood is a coal-calcareous horizon in which the coal locally attains a thickness of 2 feet.

Fauna.—Athyris sp., Chonetes sp., P. cf. *longispinus* J. Sow., *Productus sp., P. sp. nov., Schellwienella arachnoidea* (Phill.), *S.* cf. *rotundata* I. Thomas. The following forms also occur at what we believe to be the same horizon on Byers Pike. *Dibunophyllum muirheadi* Nich. and Thoms., *Pinnatopora sp., Chonetes* cf. *hardrensis* Phill., *Lingula squamiformis* Phill., *Orbiculoidea sp., Productus* cf. *longispinus* J. Sow., cf. *Schellwienella crenistria* (Phill.), *Allorisma sulcata ?* (Flem.), *Aviculopecten sp., Orthoceras* cf. *sulcatum* (Flem.), *Phillipsia eichwaldi* (Fischer de Wald.).

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In the Upper Oakwood coal-calcareous horizon the coal overlies the limestone.

Fauna.—Caninia sp., Dibunophyllum sp., Zaphrentis sp., Avonia sp., Productus giganteus (Mart.) numerous, *Spirifer sp.*

The Maiden Way Band lies midway between the Upper Oakwood and the Corbridge Limestones. No associated coal has been found.

Fauna.—Chonetes sp., cf. *Derbya gigantea* I. Thomas, *Dielasma gillingensis* (Dav.), *Lingula mytiloides ?* J. Sow., *Productus carbonarius* de Kon., *P.* cf. *longispinus* J. Sow., *P. sp.* (*' semireticulatus '*-group), *Pugnax sp., Pustula ?*, cf. *Schellwienella crenistria* (Phill.), cf. *S. rotundata* I. Thomas, *Nuculana attenuata* (Flem.).

The Corbridge Limestone is the thickest limestone above the Little, averaging 20 ft. in the north. It is poorly exposed, but has been proved in several borings. Here, as in the case of the Upper Oakwood, the coal-calcareous horizon is inverted, and the coal closely overlies the limestone.

Fauna.—Buxtonia scabricula (Mart.), *Orbiculoidea nitida ?* (Phill.), *Productus* cf. *longispinus* J. Sow., *P. martini* J. Sow., *Pugnax sp.*, cf. *Schellwienella crenistria* (Phill.), *Allorisma sulcata* (Flem.), *Myalina sp., Naticopsis sp.* A fossiliferous horizon which is believed to be approximately at the horizon of the Corbridge Limestone near the head of Crook Burn contains *Buxtonia scabricula* (Mart.), *Composita ambigua* (J. de C. Sow.), *Orbiculoidea nitida* (Phill.), *Productus pugilis* Phill., cf. *Schellwienella crenistria* (Phill.), *Spirifer sp., Aviculopecten ?, Allorisma sulcata* (Flem.), *Grammatodon reticulatus* (M'Coy), *Laevidentalium ?, Naticopsis plicistria* (Portl.) *non* Phill., cf. *Pleuronautilus nodosocarinatus* F. A. Roem., *Phillipsia sp.*

In the South Tyne, near Wydon, a marine band occurs between the Corbridge and Thornboro' Limestones.

Fauna.—Lingula cf. *squamiformis* Phill., *Orbiculoidea nitida* (Phill.), *Productus sp.* (*' semireticulatus '*-group), *Spirifer sp., Aviculopecten sp., Nuculana attenuata* (Flem.).

The Thornboro'—a normal coal-calcareous horizon—occurs some 80 ft. above the Corbridge Limestone. The coal, which is 11 inches in thickness, immediately underlies 3 ft. of pure crinoidal limestone. This is followed by 25 ft. of shaly limestone which passes up into normal shale.

Fauna.—Poteriocrinus sp., Aulophyllum fungites (Flem.), *Dibunophyllum turbinatum* (M'Coy), *Fenestella plebeia* M'Coy, *Athyris sp., Buxtonia scabricula* (Mart.), *Chonetes sp., Derbya* cf. *gigantea* I. Thomas, *Lingula squamiformis* Phill., *Orbiculoidea nitida* (Phill.), *Productus* cf. *concinnus* J. Sow., *P.* cf. *costatus* J. de C. Sow., *P.* cf. *latissimus* J. Sow., *P.* cf. *lobatus* J. Sow., *P.* cf. *longispinus* J. Sow., *P. pugilis* Phill., *Pugnax pleurodon* (Phill.), *Punctospirifer northi* Muir-Wood, *Pustula punctata* (Mart.), *Rhipidomella michelini* (L'Eveillé), cf. *Schellwienella crenistria* (Phill.), *Spirifer sp., Edmondia expansa* Hind, *Pinna flabelliformis* (Mart.), *Sanguinolites sp., Euomphalus sp., Orthoceras sp., Phillipsia eichwaldi* (Fischer de Wald.).

A thick coarse felspathic grit, here called the Thornboro' Grit, which lies about 60 ft. above the coal, is one of several horizons

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originally mapped as the base of the ' Millstone Grit'. It has been traced throughout the area.

The Lower Fell Top is a sandy crinoidal limestone, 3 ft. thick, lying a few feet above the Thornboro' Grit.

Fauna.—Derbya ?, Aviculopecten sp., Limatulina alternata (M'Coy), *Leiopteria sp., Myalina* cf. *flemingi* (M'Coy), *Protoschizodus axiniformis* (Portl.), cf. *Sedgwickia attenuata* (M'Coy).

The Upper Fell Top is a coal-calcareous horizon.

Fauna.—Buxtonia scabricula (Mart.), *Productus* cf. *pugilis* Phill., *Pugnax pleurodon* (Phill.), *Pustula punctata* (Mart.), *Schellwienella* cf. *crenistria* (Phill.), cf. *Schellwienella rotundata* I. Thomas, *Spirifer sp., Nucula lucinaeformis* Phill., *Protoschizodus axiniformis* (Portl.).

Two distinct bands of highly fossiliferous calcareous shales succeed the Upper Fell Top horizon ; both are associated with thin coals and fireclays.

Flora.—Sigillaria sp.

Fauna.—Serpulites sp., Chonetes laguessiana de Kon., *Lingula mytiloides* J. Sow., *Orbiculoidea nitida* (Phill.), *Productus carbonarius* de Kon., *P.* cf. *corrugatus* M'Coy, *P. sp.* [' *longispinus* ' group], *P. pugilis* Phill., *P. sp. nov., Punctospirifer northi* Muir-Wood, *Pustula thomasi* Muir-Wood, *Pustula pyxidiformis* de Kon., *Schellwienella crenistria* (Phill.), *Spirifer sp., Aviculopecten sp. nov. ?, Edmondia sulcata* (Flem.), cf. *E. laminata* (Phill.), *Grammatodon regularis* Hind, *Nuculana sp., Schizodus antiquus* Hind, *Conularia quadrisulcata* J. Sow.

Millstone Grit.—A grit succeeding these beds has been taken provisionally as the arbitrary base of the ' Millstone Grit.' The overlying strata up to the Low Main Coal are exposed in Kellah Burn only. They include two thin coals, and although two ' whins'[1] have been recorded from these beds in the Halton Lea Gate boring no calcareous bands have been seen at the surface.

The Low Main Coal—the lowest workable seam of the Coal Measures—has been taken as the upper arbitrary limit of the ' Millstone Grit.' Thus the ' Millstone Grit ' is here defined as a series of beds which lie between the highest strata yielding fossils of Carboniferous Limestone faunal facies and the Low Main Coal.

The Lower Carboniferous Trough of the North of England.—There is evidence that a trough of Caledonian trend exercised a strong influence during the deposition of the Upper Limestone Group and on the economic value of its coals. To obtain a true perspective, a brief examination of the Lower Carboniferous beds of the area is needful.

The recent examination of the northern part of the district has shown that beds yielding fossils of C_1 age occur in the upper part of the Cementstones, and, as these beds can be traced from the north of Cumberland across Northumberland, it is reasonable to suppose that throughout their course they are approximately of the same

[1] It has been found that the occurrence of ' whin ' in borers' records is often associated with limestone and spar, and corresponds with the position of calcareous horizons known to be persistent at the surface.

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age. Similarly, the Fell Sandstone (probably C_2) crops out in the northern part of the district, and strikes across Northumberland. Recently, it has been shown that the Scremerston coal group of Northumberland is probably equivalent to a marine-series—including the Thirlwell coal—of S age in the northern part of the Brampton district.[1]

In the south of the area, near Cumrew, along the Pennine escarpment the Carboniferous basement conglomerate immediately underlies beds of D_1 age, and, farther eastwards, two borings at Alston and Crook have reached the lower Palaeozoic floor without encountering the Scremerston Coal Group, Fell Sandstone, or Cementstones. Thus the beds below D_1 appear to have been deposited in a basin whose southern margin crosses the Brampton Sheet (one-inch 18). Furthermore there is a striking increase in thickness of the Lower Carboniferous rocks above the S zone when traced from south to north in this area. This is well illustrated by the splitting-up of the thick Melmerby Scar Limestone.

In the Upper Limestone Group many coal-calcareous horizons gradually die out southwards. Indeed the southern limit of workable seams, within both the Upper and the Middle Limestone Groups, is closely related to the southern margin of the trough. The coals lying below the Scar, 5 Yard, and 3 Yard Limestones of the Middle Limestone Group have been worked in the north, but are either absent or too thin to work in the southern (Alston) sequence. Moreover the strata of this Group in the latter area are 800 ft. thick as compared with 1,200 ft. in the north.

In the Upper Limestone Group, again, the Little Limestone Coal, which is, and has been, extensively wrought in the trough to the north, reaches a maximum thickness of 6 ft. 2 in., but is not more than 1 ft. 6 in. in the Alston area. The Oakwood coal, 2 ft. thick in the north, gradually thins and eventually disappears southward. This coal is correlated with the Lickar of Northumberland; it and the Little Limestone Coal are the most important coals of the Upper Limestone Group of the North of England. Several of the thinner coals are not present at Alston, but the Firestone Sill Coal and that below the 'Fell Top' of Alston thicken locally in that area. Only two limestones are known above the Great in the Alston sequence—the Little and the 'Fell Top' of Westgarth Forster.[2] Field mapping has shown that the latter is really the Middle Oakwood. The strata between the Great and Forster's 'Fell Top' thicken from 450 ft. at Alston to 730 ft. in the trough to the north. No definite correlation is possible between the beds in the northern area and those of Alston above the 'Fell Top', owing to the absence of calcareous bands in the latter area. The strata between the 'Fell Top' of Alston and the base of the Coal Measures are much thinner, according

[1] Trotter, F. M., 'The Lower part of the Carboniferous Limestone Series (with the Thirlwell Coal) in the Brampton and Gilsland Districts,' 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 160–1.

[2] *Op. cit.*, pp. 92–95.

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to Westgarth Forster,[1] than the corresponding strata in the trough, but there is a possibility of an unconformity or a non-sequence at the base of the Upper Carboniferous in both areas.

The trough shown to exist in North-east Cumberland and Northumberland is not restricted to those districts, for Dr. B. Smith[2] has shown that a thick group of strata with thin calcareous horizons overlies the First (or Great) Limestone on the northern side of the Lake District. These strata are not present at Whitehaven, but may have been denuded, as an unconformity is believed to exist at the base of the Upper Carboniferous of that area.[3]

At the north end of the Isle of Man a suite of recent borings[4] has proved beds corresponding in thickness and lithology with the Upper Limestone Group of the trough.

Jukes-Browne[5] has given reasons for supposing that the Southern Uplands remained as a land ridge of Caledonian trend throughout Lower Carboniferous times and probably this ridge marks the northern limits of the trough.

The southern limits of the trough approximately coincide with the northern limits of a ridge which according to Goodchild[6] extended from the Isle of Man to the Durham coast. Woolacott[7] doubted its existence in Durham, but work in North-east Cumberland, and the evidence of the above-mentioned Isle of Man bores, favours Goodchild's view in confirming the northern boundary of this ridge.

Thus, a well-developed trough appears to have existed throughout Lower Carboniferous times, the southern margin of which extended from the Isle of Man, across the northern end of the Lake District, to the Durham coast. South of this line the Cementstones, Fell Sandstone, and Scremerston Coal Group are absent and no good workable coals are present in the Middle and Upper Limestone Groups.

Correlation.—The Upper Limestone Group was put in Dy (=D_3)[8] by Vaughan and this was adopted by Dr. S. Smith.[9] But D_3 as redefined in the Report of the British Association Committee[10] and their succeeding Orionastrea Zone lie wholly below our Upper Limestone Group. The report did not discuss the classification of

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[1] *Op. cit.*, pp. 91–93.

[2] 'On Borings for Coal near Maryport, Cumberland,' 'Summary of Progress' for 1920 (*Mem. Geol. Surv.*), 1921, pp. 85–91.

[3] 'A Sketch of the Geology of the Whitehaven District,' *Proc. Geol. Assoc.*, vol. xxxvi, pt. 1, 1925, pp. 52–3.

[4] Smith, Dr. B., see Appendix III, pp. 108–119.

[5] 'The Building of the British Isles,' Ed. 4, London, 1922, p. 158.

[6] Goodchild, J. G., 'An outline of the Geological History of the Eden Valley or Edenside,' *Proc. Geol. Assoc.*, vol. xi, p. 269.

[7] Woolacott, D., 'On a boring at Roddymoor Colliery, near Crook, Co. Durham,' *Geol. Mag.*, 1923, p. 53.

[8] Edmonds, C., 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag.*, 1922, p. 127.

[9] In 'Faunal Succession of the Upper Bernician,' *Trans. Nat. Hist. Soc. Northumberland, Durham and Newcastle-upon-Tyne*, New Series, vol. iii, pt. 3, 1910, pp. 600–2.

[10] 'Report of the Committee on Lower Carboniferous Zonal Nomenclature,' *Rep. Brit. Assoc.*, 1925 (1926), pp. 258–264.

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these overlying beds and left open the question of their relationship to the Lancastrian. The dividing line between the Upper and Lower Carboniferous has been defined in terms of the flora and fishes by Kidston and Traquair respectively, and by means of goniatites by Mr. Bisat. The coral-brachiopod fauna, which on the whole is characteristic of the Lower Carboniferous, is known to persist well into the Upper Carboniferous. Mr. Bisat has shown that the floral and goniatite breaks do not coincide; he suggests that the former occurs within the Lancastrian at the top of the Eumorphoceras Zone or low down in the Homoceras Zone.[1]

With regard to the sequence now discussed: Mr. Bisat has examined a goniatite found in the Thornboro' Limestone and states in correspondence that "Its suture is of Beyrichoceras type. This definitely excludes any upper Carboniferous genus except Eumorphoceras, and I see no trace of the ribs of that genus. Its affinities are therefore more Lower Carboniferous than Upper Carboniferous."

The Eumorphoceras Zone lies below the floral break; so that if that break be taken as the dividing line between the Upper and Lower Carboniferous, then the strata up to, and including, the Thornboro' Limestone fall within the Lower Carboniferous, and this is probably also the case if the goniatite break be taken as the divisional line.

There appears to be a continuous upward sequence from the Thornboro' Limestone not only in this district, but also throughout Northumberland. The Fell Top Limestones and the fossiliferous shales which lie some 250 ft. higher than the Thornboro' Limestone (Fig. 1) agree in faunal facies with those below this limestone and these beds also may be Lower Carboniferous. If this be so, the Lancastrian, thousands of feet thick in Yorkshire and Lancashire, would be represented by the 300 ft. of beds which lie between the highest fossiliferous beds of the Upper Limestone Group and the Westphalian Coal Measures; or, as seems more probable, a concealed unconformity or a non-sequence would exist. An unconformity lies at the base of the Lancastrian in the Whitehaven district.

Lebour[2] correlated the Great Limestone of Alston and Durham with the Dryburn of Northumberland, and Gunn[3], who accepted this correlation, has given reasons for correlating the Dryburn with the Main of Yorkshire and the limestone [Hosie] which lies below the Edge Coals of Scotland. Mr. Edmonds[4] has proved the faunal and lithological identity of the Great Limestone and the First Limestone of Whitehaven. We accept these relationships.

The strata above the Great Limestone of our area contain more fossiliferous marine horizons than have been recorded elsewhere

[1] Bisat, W. S., 'The Carboniferous Goniatites of the North of England and their Zones,' *Proc. Yorks. Geol. Soc.*, New Series, vol. xx, pt. 1, 1923–4, p. 47.

[2] Lebour, G. A., 'Outlines of the Geology of Northumberland and Durham,' Ed. 3, 1889, Newcastle-upon-Tyne, pp. 61–2.

[3] Gunn, W., 'Notes on the Correlation of the Lower Carboniferous Rocks of England and Scotland,' *Trans. Geol. Soc. Edin.*, vol. vii, 1899, vert. sect. opp. p. 362.

[4] *Op. cit.*, pp. 123–24.

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in the North of England and South of Scotland, but definite correlation of individual beds in our sequence with those of outside areas must await further collecting of fossils from those districts. Owing to the persistence, however, of the chief limestones in the Upper Limestone Group a lithological comparison with the Tyne area may be made with every confidence, and the names adopted for definite strata in that area have been used for their equivalents in North-east Cumberland. Local names have been given only to those fossiliferous horizons which at present are not known to extend into Northumberland. It has been shown[1] that individual limestones can be traced from the Tyne district across Northumberland.

The coals between the Great and the Lower Oakwood Limestones may be correlated with the Kilnholm coals of Canonbie and the Edge Coals of Scotland.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 85.

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APPENDIX III

On the Carboniferous Limestone Series of the Northern Part of the Isle of Man

By Bernard Smith, M.A., Sc.D.

Text-figures 1, 2, 3.

The sequence of Carboniferous rocks as displayed in the south of the Isle of Man received full treatment by Lamplugh in his memoir on the Geology of the Isle of Man ; and the palaeontology has been reviewed more recently by Wheelfon Hind.[1]

It has been realised for some time that probably a still fuller sequence of Carboniferous rocks was likely to occur beneath the drift-covered northern plain of the island, and Lamplugh was able to give details of such rocks proved in four borings out of six[2] that had been put down along the Ayre, on the northern coastline, by Messrs. Craine Bros. of Liverpool, between 1891 and 1903, the date of publication of the Memoir. From these borings he deduced that Lower Carboniferous rocks cropped out beneath the Glacial drifts over the greater part of the northern plain, but were succeeded to the north and east by Permo-Triassic deposits.[3] Towards the south they overlay the Manx Slates. He concluded that the already proved extent and diversity of these rocks indicated that their aggregate thickness must be great, certainly far exceeding that of the Carboniferous strata of the south of the island ; it might reach some thousands of feet.

As it was incumbent upon him to make a ' solid ' map of this drift-covered part of the island, he prepared a frankly conjectural map in which the New Red Rocks are shown faulted against the Carboniferous Limestone Series on the south-west, but overlying them uncomformably on the south-south-west (Fig. 1). This fault reached the surface between the Lhen (No. III) and Ballawhane (No. II) borings of the first series. Southward he covered nearly all the ground as far as the present mountains with Carboniferous Limestone and supposititious Basement Beds—the most reasonable solution of his difficulty with the facts then available.

Further light has now been thrown upon the problem by a series of no less than 20 bores for haematite which have been made, since 1920, by the Coltness Iron Co., Ltd., of Newmains, Lanarkshire, through whose courtesy we are enabled to publish the geological

[1] ' The Palaeontological Succession of the Carboniferous Rocks in the South of the Isle of Man,' *Proc. Yorks. Geol. Soc.*, 1907, vol. xvi, pt. ii, pp. 137–154.

[2] ' The Geology of the Isle of Man ' (*Mem. Geol. Surv.*), 1903, pp. 280–295, Pl. V.

[3] For a further discussion of these deposits, after the sinking of another (the seventh) bore, see Prof. J. W. Gregory ' The Red Rocks of a Deep Bore at the North End of the Isle of Man,' *Inst. Min. Eng., Scotland*, vol. lix, pt. 2, 1920, pp. 156–68.

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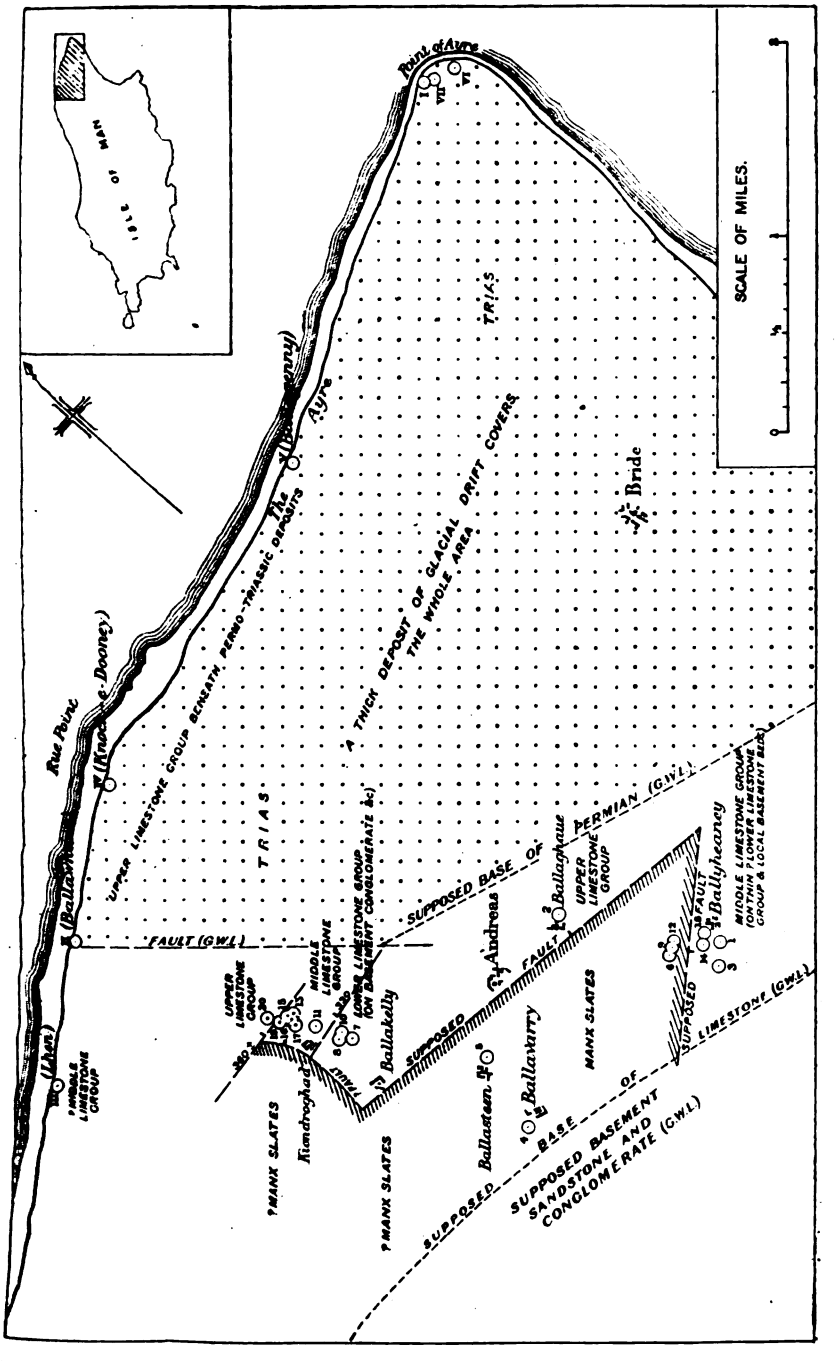

FIG. 1.—*Map of the Northern Part of the Isle of Man; showing sites of bores and probable boundaries of solid rocks.*

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results. Fortunately the writer was free to accept an invitation to examine the cores of the first two bores put down, and for this purpose visited the island in the spring of 1921 in the company of Mr. J. B. Atkinson, and Mr. J. A. MacVicar of the Sullivan Machinery Co. by whom the bores were made.

The palaeontological evidence obtained was scanty; hence the deductions made below as to the sequence are based mainly upon lithology.

Sequence.—Five of the bores, Nos. 4, 5, 6, 9, and 12, were in the Manx Slates. The remaining fifteen may be grouped as follows:—(1) Nos. 7, 8, 10, and 11; (2) Nos. 11, 13, 15, 16, 17, and 19; (3) No. 20; (4) No. 2; (5) Nos. 1, 3, 14, and 18.

(1) The lowest beds in the sequence are obviously the conglomerates and shales underlying the lowest limestone in B.H. 7 (Fig. 3) and may be classified as the lowest basement beds found to date. From their very nature the horizon of any basement beds will vary from point to point—as will be seen by reference to other bores, more especially 1, 3, 14, and possibly 8—and in places may be wanting altogether; they are merely a local phase at the base of the Carboniferous, where the latter overlies the Manx Slates. In B.H. 7 they are succeeded upwards by thin limestones and shales with conglomerates, bands of quartzite and sandstone, and occasional thin threads of coal. Overlying these (B.H. 7 and 8) is limestone split up by numerous beds of shale with some threads of coal. In B.H. 7, 8, 10, and 11 these are succeeded by a thick conglomerate and grit with occasional bands of limestone and streaks of coal. Alternations of limestone and shale then supervene, with an odd band of grit or conglomerate, until we come to the sequence proved in the second group of holes, with which B.H. 11 forms a link.

(2) These holes prove a thick mass of limestone with few or no definite bands of shale, except near its base, where the most marked is a black shale recognisable in most of the bores. The upward limits of this limestone are unknown, but it is conjectured that almost its full thickness was penetrated in B.H. 13.

(3) Now comes a gap in the sequence; but it is probable that the record of the contiguous B.H. 20 follows closely upon that of the last group. Here the limestones are becoming split up by shales, and finally give place upwards to a shale and sandstone group.

(4) For the remainder of our sequence we turn to the record of B.H. 2. This hole is isolated from the remainder, and the rocks are of a distinct type. It is essentially a shale group with three horizons at which limestones are developed. The lithology is described below.

(5) B.H. 1, 3, 14, and 18 appear to have penetrated part of the thick limestone group, with some thinner limestones and shales overlying a local conglomerate near the base. A description of B.H. 1 will be found further on.

Suggested Correlation.—The above sequence, generalised (Fig. 2), and exclusive of gaps, amounts to 2,032 ft., which is far in excess of that of the Lower Carboniferous rocks of the south of the island, as suspected by Lamplugh, who, furthermore, thought it probable that the Carboniferous rocks of the north of the island would eventually "be found more to resemble the rocks of the same age in Scotland than those in Cumberland[1]"—and by this he no doubt meant West Cumberland.

The truth seems to lie between the two, for the lower part

[1] 'The Geology of the Isle of Man,' *op. cit.*, p. 293.

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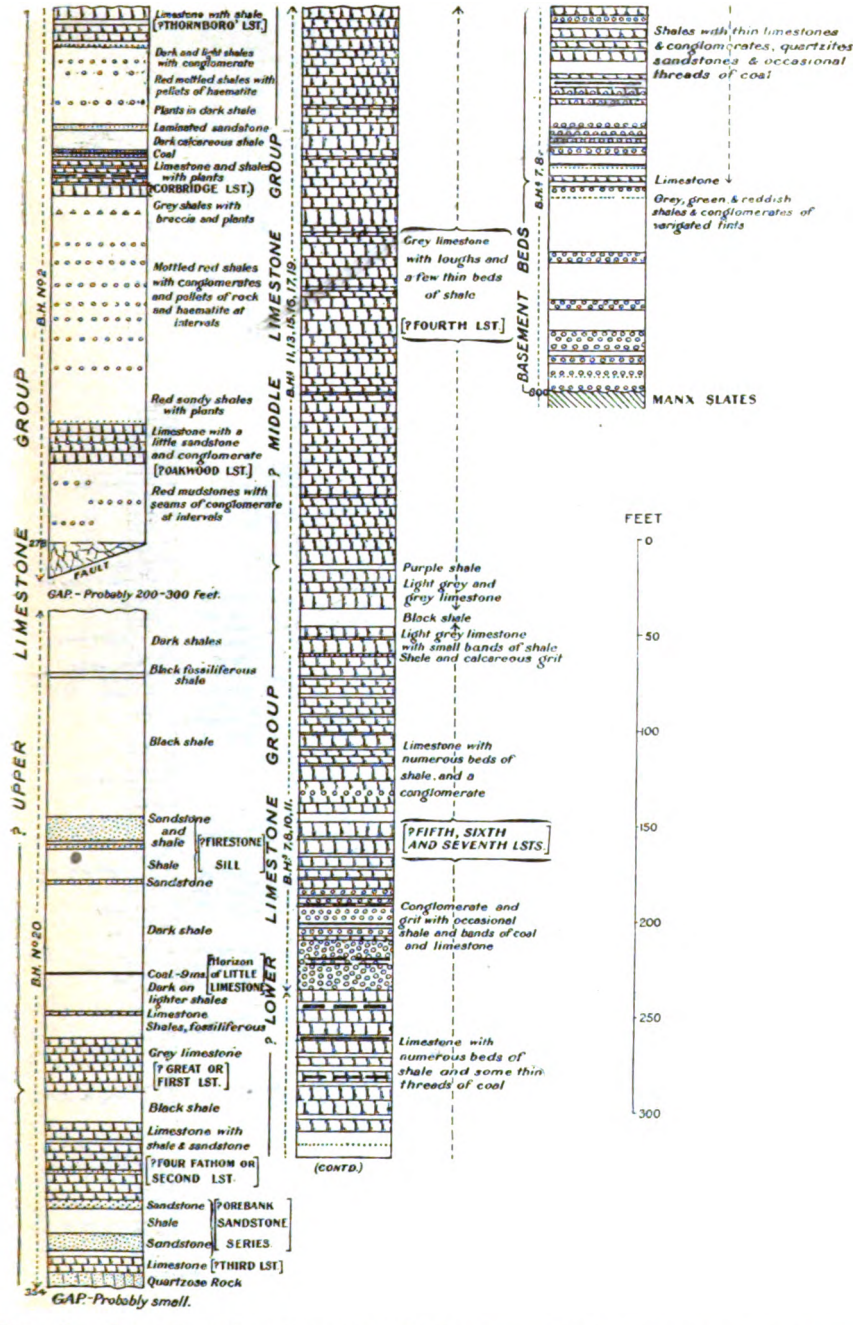

FIG. 2.—*Generalised Sequence of the Carboniferous Rocks of the Northern Plain of the Isle of Man; deduced from a series of 20 boreholes.*

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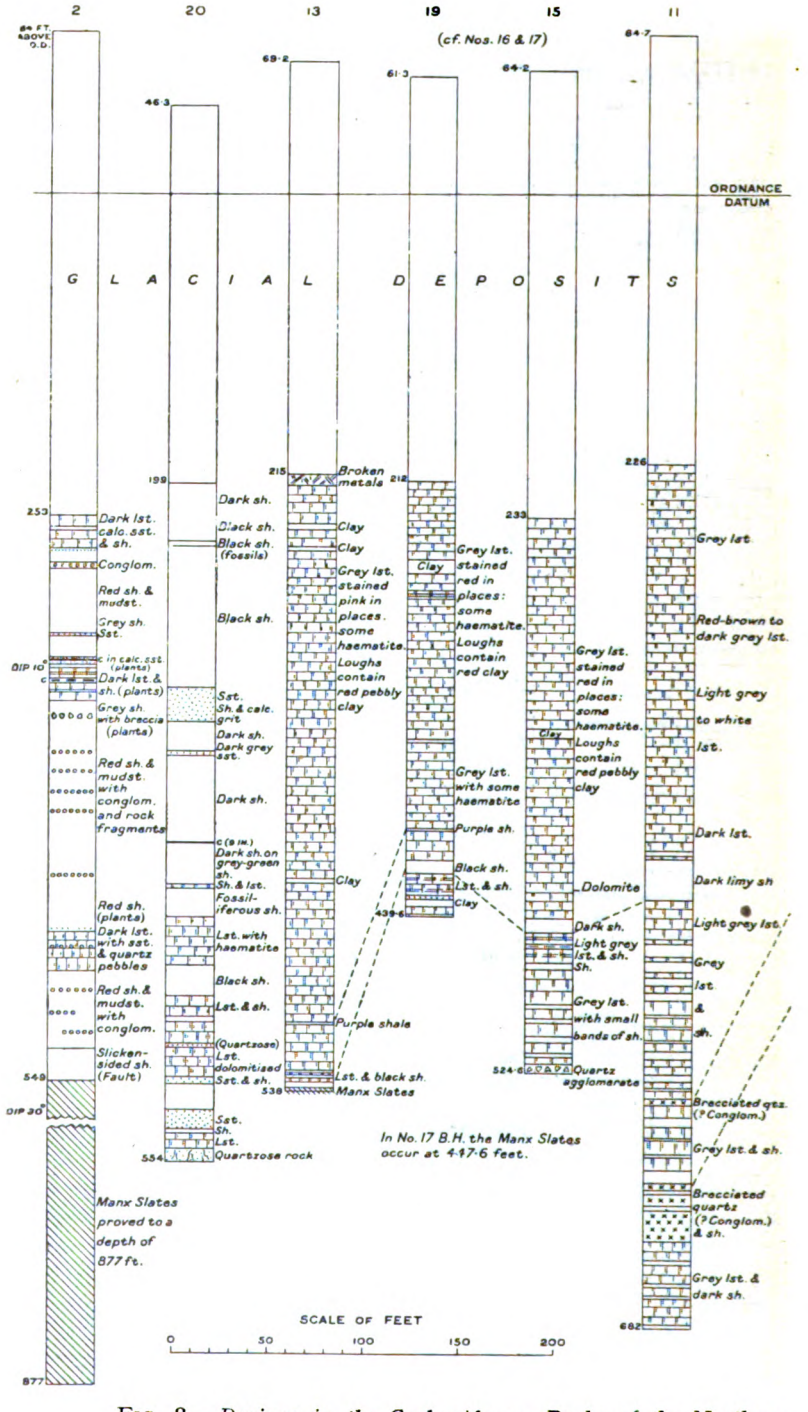

FIG. 3.—*Borings in the Carboniferous Rocks of the Northern*

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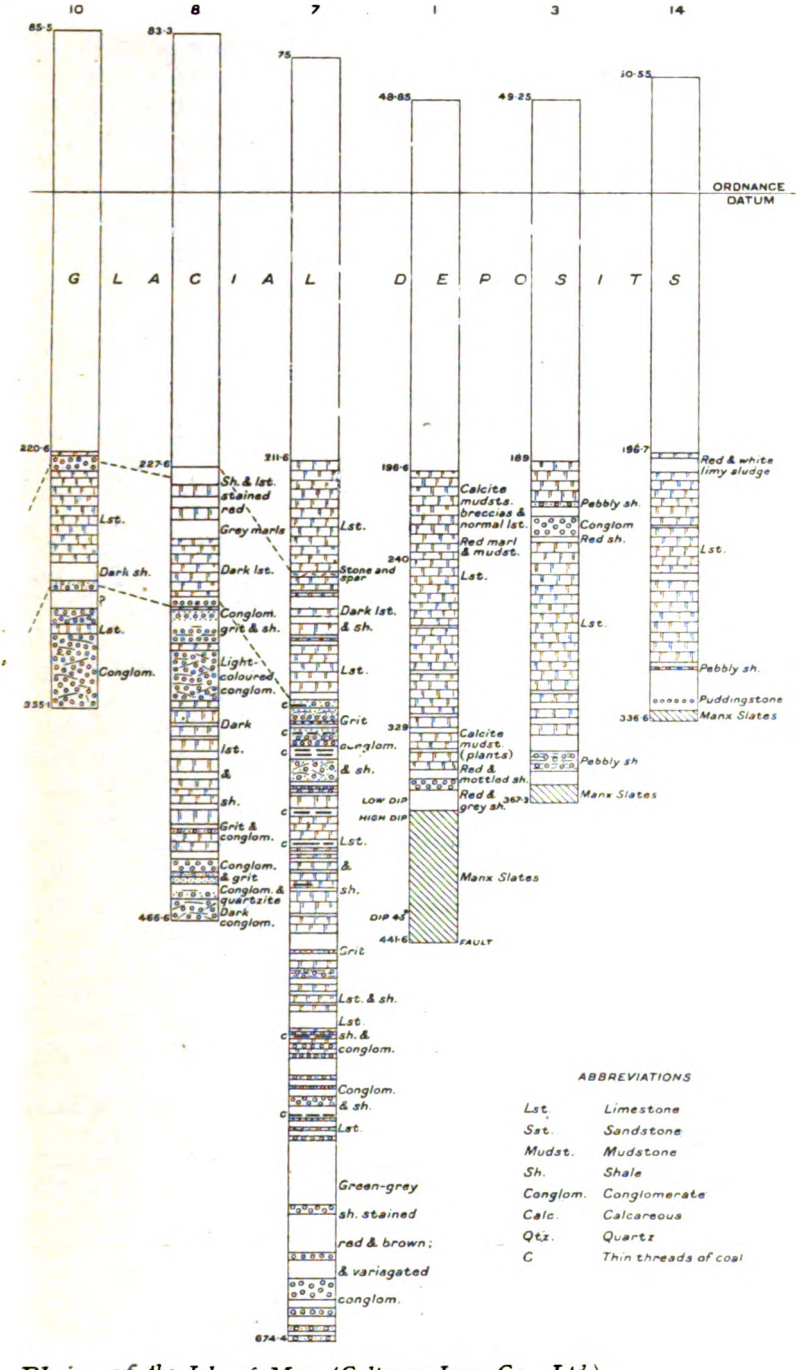

Plain of the Isle of Man (Coltness Iron Co., Ltd.).

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of the sequence appears to be related to that of West Cumberland,[1] whilst the higher part may be compared with that in East Cumberland[2] (and probably that part of Cumberland which lies mainly north of the Lake District). In the absence of much palaeontological evidence any accurate correlation is impossible, and that now suggested must be taken to be no more than approximate and tentative.

The fossils (p. 116) found in B.H. 1 have been determined by Mr. J. Pringle to be probably D_2 (Upper Dibunophyllum Zone) forms. Since the greater part of the 'Fourth Limestone' (the thick limestone of the West Cumberland sequence and part of the Middle Limestone group of that area) is D_2, the correlation between it and the thick massive limestone of the north of the island is assumed to be approximately correct. With this as our only basis of correlation by faunas it is suggested that the beds from somewhere about the horizon of the purple shale, near the base of the thick limestone (Figs. 2 and 3) down to the base of the lowest limestone may be equivalents (D_1 and Upper S_2 Zones) of the Lower Limestone Group of West Cumberland, and may thus represent, in the main, all the limestones below the *Girvanella* horizon at the base of the Rough Beds of the Fourth Limestone in the Whitehaven District. These are known as the White Beds of the Fourth Limestone, and the Fifth, Sixth and Seventh Limestones. The Isle of Man beds may indeed extend to still lower horizons, as do the limestones near Millom and Brampton in Cumberland. The black shale mentioned above (p. 110), which is somewhat lower than the purple shale, would then represent the Fourth Shale which underlies the White Beds at the base of the Fourth Limestone of Whitehaven.

Borehole No. 20 carries our correlation upwards in the Middle Limestone group through what may be the equivalents of the Orebank Sandstone Series of Whitehaven, to the First Limestone or its equivalent the Great Limestone of East Cumberland. From this point upwards the sequence is suggestive of that established in East Cumberland for the Upper Limestone Group, although shales are more prominent than sandstones in these boreholes. The absence of a limestone representing the Little Limestone would be disconcerting were it not for the presence of a 9-in. coal—the thickest discovered in the island—which may be the Little Limestone Coal, the latter being the most important coal in the Limestone sequence in East Cumberland.

The widely separated limestones in the higher shales of B.H. 2 are strongly suggestive of limestones that occur above the Little Limestone. The reason for assuming that the middle one—that overlain by a thin layer of coal—is equivalent to the Corbridge Limestone is because the latter, as determined by Mr. Trotter in

[1] Edmonds, C., 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag.*, 1922, pp. 74–83 and 117–31. Also B. Smith, E. Dixon, T. Eastwood and C. Edmonds in 'A Sketch of the Geology of the Whitehaven District,' *Proc. Geol. Assoc.*, vol. xxxvi, pt. 1, 1925, pp. 41–5.

[2] Trotter, F. M., in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 89–2, and Brampton section, Fig. 6, p. 81.

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East Cumberland, is the only one in the Upper Limestone Group which has a coal actually at its surface. Unfortunately the fossils obtained from B.H. 2 were either undeterminable or of little value.

Turning now to the previous bores described by Lamplugh. The most probable downward sequence of the concealed Carboniferous strata is said by him to read as follows :—

3. Sandstones and shales, with thin limestone bands in the lower part.
2. Limestones.
1. Sandstones and conglomerates of the Peel Series[1].

This arrangement agrees fairly well with that obtained from the new series of borings except for the fact that in the latter case limestones occur at intervals throughout the upper division.

It is clear that the beds traversed in B.H. III (Lhen), II (Ballawhane), IV (Knock-e-Dooney) and V (Ballagenny)[2] represent, on the whole, an ascending but probably faulted sequence, apparently from near the top of the thick limestone group (that in the Lhen B.H.) upwards ; hence those in the last three holes seem to belong to the Upper Limestone Group.

Apart from the general similarity of these upper beds in the old and the new suites of bores, individual portions of the sequence cannot be recognised as strictly comparable. The rocks in the Ballawhane and Knock-e-Dooney holes *may* be somewhere about the horizon of the middle part of the series proved in B.H. 20. Those in the Ballagenny bore are probably higher, and the thick sandstones of that bore are not represented in the new series. There all comparison ends, and the fossils recorded by Lamplugh from the last hole do not give much help in the determination of their exact horizon, for the forms have a considerable range throughout the higher part of the Lower Carboniferous Series.

With regard to the succession in the south of the island, a rough correlation may be made between the Castletown and Poolvash Limestones and the thick limestone of the north, for the former are mainly of the higher Dibunophyllum zone (D_2)[3], although some Cyathaxonia beds are present in the Castletown (or 'Lower') Limestones.

B.H. 1, described below, showed no real signs of the presence of reef knolls like those in the Poolvash Limestone[4]. Contemporaneous breccias, however, are present.

No representatives of the Posidonomya Beds of the south have yet been recorded from the northern area.

Conditions of Deposition.—The rocks were evidently deposited upon an uneven surface of Manx Slates, apparently in such a manner that the hollows in that surface tended to become levelled up with conglomerates and shales, as well as with the succeeding thin-

[1] As there appears to be some doubt as to the age of the Peel Sandstones, this had better be taken to mean Basement Beds.
[2] A full description is given in 'The Geology of the Isle of Man,' *op. cit.*, pp. 281–91.
[3] Hind, Wheelton, *op. cit.*, pp. 147 and 150.
[4] Lamplugh, G. W., *op. cit.*, pp. 249–50.

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bedded limestones, shales and conglomerates, before the thicker limestone was deposited over a much more extensive area. Where most of the beds lower than the thick limestone are missing (as in B.H. 1) the basement conglomerates are thin; where those beds are well represented (as in No. 7) the conglomerates are thick. During the deposition of the Lower Limestone Group the sea was shallow and frequently shoaled sufficiently for thin bands of coal to be formed.

During the succeeding Middle Limestone period the sea was freer from debris from the land although—as in the Whitehaven District—it may have been comparatively shallow and the deposits occasionally of lagoon-phase type. In No. 1 B.H., for example (Fig. 3) the higher part of the limestone contained many peculiar types of rock. The highest 9-10 ft. of limestone beneath the base of the drift, at 196 ft. 8 in., was pale coffee-coloured or brown calcite mudstone, brecciated here and there, with the fragments set in a greenish marly matrix. Below this there were, in more normal limestones, several bands of breccia which consisted in places of fragments both of calcite mudstone or normal limestone and of marl. Occasionally pebbles from an extraneous source were present. At 233 ft. a red mottled marl set in, with rock fragments including pellets of nearly black ore which crushed to a brown or dull brick-red tint. This overlay about 2 ft. of red mudstone resting on a 'brockram' of red sandy and green marl with fragments of crinoidal limestone. Below this, from 240 ft. to 329 ft. depth, was a more normal fossiliferous crinoidal limestone with an occasional band of shale and some dolomite. At 329 ft. there was a shale full of root-lets. Calcite mudstones occurred again at about 340 ft. and over-lay mudstones (in places very like fireclay) with plant remains and pellets of shale and conglomerates mostly composed of the latter. Variegated mudstones and shales occurred at the base with scattered pellets of haematite. The fossils obtained from this boring are as follows[1]:—

Plant fragments.
Crinoidal ossicles.
Lithostrotion junceum (*Flem.*)
,, martini? *Edw. & Haime.*
Syringopora sp.
Productus sp. (prob. fragment of P. giganteus *Mart.*).
Productus sp.
Spirifer sp.

The conditions were somewhat different from those at B.H. 1, 3, 14, and 18 when we get further away from the land and lower beds come in, as in the northern cluster of bores. Here the thick limestone appears to be more consistent and more pure, though an examination of the cores might have revealed shallow-water phases.

The higher part of the Middle Group shows signs of the increase of terrigenous sediments, albeit limestones were still deposited at intervals throughout the deposition of the Upper Group.

The upper part of the latter, as revealed in B.H.2, is of interest. The beds between the limestones are red in tint and full of washings

[1] Preserved in the Survey collections and numbered B.S. 1840–60.

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from a neighbouring land, which evidently lay to the south. They consist of shales and mudstones with occasional seams of conglomerate and breccia, or with isolated fragments of extraneous rock, such as shale, slate, grit, vein quartz, volcanic rock including ash, and pellets of haematite. The latter, if derived, must have come from some pre-Carboniferous outcrop, as they are similar to those occurring in the Basement-Beds at B.H. No. 1.

Near the limestones, the shales are usually grey and contain remains of plants. With regard to the fossils obtained,[1] the plant remains and corals were indeterminable. *Productus sp.* occurred at 255 ft., and a Rhynchonellid was present at from 342-7 ft.

Area of Deposition.—The mode of occurrence of the Carboniferous rocks both in the north of the island and in the south suggests that the central parts of the island stood out above the Carboniferous sea for part at least, if not all, of the Lower Carboniferous period,[2] but the sea was steadily encroaching on the flanks of the slowly sinking land.[3] Whether totally submerged or not the latter formed a ridge that was instrumental in aiding in the separation of an area of deposition to the north from another to the south[4] which differed considerably in the character and thickness of their contained deposits. Those on the northern side of the island belong essentially to the southern parts of a great northern basin, the axis of which appears to have trended roughly in an east-north-east direction.

The 'Solid' Map.—The map, Fig. 1, whilst furnishing new facts, must still be tentative as regards the actual boundaries of the geological formations.

It seems evident that there is a gradual oncoming of higher beds in the Limestone Series as we pass from B.H. III to B.H. V, but there may be several undetected faults in this area.

West of the fault between II and III the dip of the limestones appears to be south-eastward as far as a fault with northern downthrow between B.H. 20 and the cluster 11, 13, 16, 17, and 19. Between 11 and the cluster 10, 8 and 7, a second fault with northern downthrow supervenes. From 10 to 7 the dip is southerly, and this may be continued as far as B.H. 2, in which the highest beds in the new suite of bores are found. Yet there may be several intervening faults. The fault shown south of B.H. 2 was detected by the writer in the cores, and since 4, 5, 6, 9, and 12 all entered Manx Slates beneath the Glacial drift, its trend must be approximately as shown, unless there is more than one fault separating the Limestone Series from the Slates.

In B.H. 1 there was no sign of a fault at the junction with the Slates, and the sequence in the neighbouring three holes (3, 14, and 18) is similar, yet a fault throwing up the Manx Slates at 6, 9, and 12

[1] Preserved in the Survey collections and numbered B.S. 1861–80.
[2] Hind, Wheelton, *op. cit.*, p. 151.
[3] Lamplugh, G. W., *op. cit.*, p. 193.
[4] For correlation of the southern rocks with those on the mainland and in Ireland see Hind, *op. cit.*, pp. 147–153.

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must lie between the latter and Nos. 14 and 18. This may have been reached at the very bottom of B.H. 1 where poorly cleaved slickensided shales and mudstones of the Manx Series were entered. Its approximate trend is indicated on the map.

The dip of the rocks between 14-18 and 3-1 appears to be south-south-eastward, hence there is probably a considerable spread of the Limestone Series in this direction.

B.H. 13 and 17 encountered slate at depths (related to O.D.) which suggest a floor or surface of Manx Slates rising westward to crop out at the base of the Glacial deposits at about 200 yds. south-west of No. 17 hole. Read in conjunction with the presence of a great thickness of the Lower Limestone Group in B.H. 11 this surface is suggestive of a fault of low inclination.

It is clear that a considerable area of the ground conjectured by Lamplugh to be occupied by Carboniferous Limestone and Basement Beds must be relegated to the Manx Slates.

The Manx Slates.—The Manx Slates, as seen by the writer in B.H. 1 and 2, consisted of alternations of bluish-grey or green (in places purple) shales and mudstones showing cleavage, with sandy mudstones and fine sandstones and grits. Some beds appeared to be ashy sandstones and grits or fine ashes, and others were of a fine greywacke type. At the bottom of No. 1 hole poorly cleaved soft grey shales and mudstones resembled Skiddaw Slates, whilst near the base of No. 2 hole bands of tough micaceous grit contained pebbles of vein quartz. In B.H. 9 the beds were penetrated to a depth of 319 ft. 3 in. from the surface (Table, p. 119) and are recorded as a series of predominantly hard shales of variegated tints.

Glacial Deposits.—The Glacial deposits consist of alternations of sands and gravels and of boulder-clays, in places showing a tripartite or quadri-partite arrangement, which is a characteristic of the drifts of the Carlisle plain.[1] Their most remarkable feature is their very regular thickness over the area of about 4½ sq. miles proved by these new bores. The floor upon which they rest is almost a flat plain in which the lowest part (−169 ft. O.D. in B.H.2) is only 34 ft. below the highest part (−135 ft. O.D. in B.H.10). This forms part only of a widespread pre-Glacial marine platform which descends very gradually in the direction of No. V B.H. where it lies approximately at −192 ft. O.D. Farther in the direction of the Point of Ayre the pre-Glacial rock surface steepens and at the Point itself may be actually beyond the limits of the marine platform.

[1] 'The Geology of the Carlisle, Longtown and Silloth District' (*Mem. Geol. Surv.*), 1926, p. 47.

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ISLE OF MAN BORINGS, COLTNESS IRON CO., LTD.

Number of Borehole	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20
Height above O.D.	48·85	84·00	49·25	61·00	73·75	63·05	75·00	83·30	66·05	85·50	84·70	65·80	69·20	60·55	64·20	70·30	73·80	70·20	61·30	46·30
Glacial Deposits	196·6	253	189	202	227	215·4	211·6	227·6	224	220·6	226	231·5	215	196·7	233	227	227	216·7	212	199
Upper Limestone Group	—	278 and Fault 18	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	—	250·6
Middle Limestone Group	135·6	—	123·9	—	—	—	—	—	—	—	189	—	289·6	104·11	193	213	183	98·5	181·9	104·6
Lower Limestone Group	?17·5	—	?17·6	—	—	—	351·6	198·9 + ?40·3	—	134·7	267	—	31·6	?4	93·6	29·6	37·6	?8	45·9	—
Basement Beds	22·7	—	26·9	—	—	—	111·4	or [?40·3]	—	—	—	—	—	25·2	Quartz Agglom-merate 5·0 ? Fault	—	—	20	—	—
Manx Slates	69·6	328	10·3	11·3	16·3	12·8	—	—	95·3 (Shales)	—	—	10·7	2·0	5·10		—	2·0	11·7	—	—
Total depth	441·6	877	367·3	213·3	243·3	228·0	674·4	466·6	319·3	355·1	682·0	242·0	538	336·6	524·6	469·6	449·6	354·7	439·6	554

In the above table the thicknesses of the divisions follow, as closely as possible, the classification suggested in the text. Heights above O.D. are in feet and decimals. Thicknesses and depths are in feet and inches.

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APPENDIX IV

Note on a 'Want' proved in the Five Foot Seam in the Cowdenbeath District of Fife

By J. K. Allan, M.A., B.Sc.

Text-figure 1.

In the workings of the Five Foot Coal in the Cowdenbeath District of Fife the seam has been proved to thin out or even disappear entirely along a narrow area extending in an approximately north and south direction for a distance of about five miles between Hill of Beath and Lochore. From information kindly supplied by the Fife Coal Co., the Lochgelly Iron and Coal Co., and Messrs. Wilsons and Clyde it has been found possible to prepare a map (Fig. 1) showing the course of this belt of thin coal, and to supply the following details.

(1) The want can be traced from a point just east of the Mary Pit, Lochore, in a direction slightly west of south, to a point between the Mossbeath and James Pits, where it strikes west by Dalbeath Pit to the Kingseat area. Information as to its further extension in this direction has not yet been obtained.

(2) Its course is streamlike, sweeping in gentle curves, with a decided widening towards the south and west. At its narrowest point, west of Glencraig, it is 260 ft. broad. At No. 8 Pit, Cowdenbeath, it has a width of about 450 ft., while its greatest known width, at Dalbeath Pit, is about 550 ft.

(3) Where the coal has been worked up to the want from both sides there is no discrepancy in levels. Level courses can be continued across the thin belt and fit in with corresponding contours on the opposite side ; nor does the dip of the seam change abnormally.

(4) The thinning is confined to the coal and does not, so far as is known, affect the pavement of the seam at any point. North of the Hill of Beath and just west of the area shown in Fig. 1, a series of underground bores were put up from the Dunfermline Splint seam, and reached the Five Foot position six fathoms or so above it. The normal thickness of the coal was found to be from 50 to 55 inches, with a thin and variable pavement of fire-clay resting on a thick bed of faky sandstone, and a roof of dark fakes. Within definite north and south limits in the series of bores the coal diminished to nine, and in one case to four inches, while the pavement and roof remained constant. At Dalbeath Colliery, where the shaft passes through the want, the coal is only one foot six inches thick, and rests on fireclay overlying faky sandstone. No coal was recorded at the Five Foot position in No. 8 Pit, Cowdenbeath, but the strata can be

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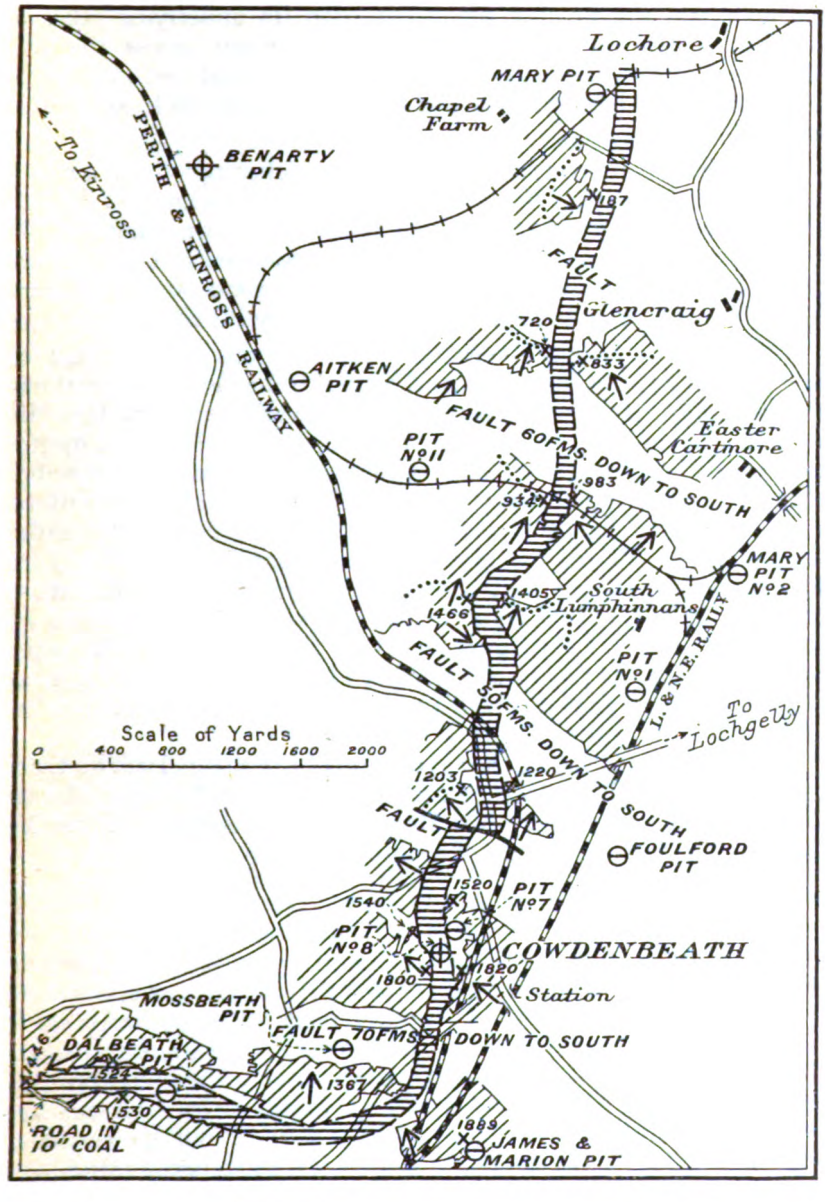

FIG. 1.—*Plan of area of thin coal in Five Foot Seam, Cowdenbeath District.*

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closely correlated with the adjoining No. 7 Pit, where the seam is normal, and the fireclay pavement with its underlying fakes and sandstone can be recognized. A mine driven across the want, 600 yds. W. from Dalbeath Pit, passed from normal coal on the south-east, through a belt where it was only ten inches thick, and reached normal coal beyond.

(5) There is no continuous abnormal thickening of coal along the margins of the want. West of the James Pit a thickness of 72 inches is recorded, but generally the coal thins from normal fairly rapidly to an unworkable seam. The final working-faces at Dalbeath were from 19 in. to 30 in. ; at No. 8 Pit they were 30 in. ; at South Lumphinnans 18 in. to 27 in. ; and at the Mary Pit 25 in.

(6) Definite evidence regarding the relations between the coal and its roof has not been obtained owing to the closing of sections of the workings, but it would seem that the overlying strata have filled up a channel in the coal-forming material, a channel which sometimes cut partially through it, and sometimes reached the underlying clays. It seems likely that the want is the channel of a Carboniferous stream, flowing sluggishly over the marshy flats of a slowly sinking land margin. Where the stream curved sharply, as at the James Pit, there is evidence that a spit was formed jutting out into the channel, for we find that layers of clay and sand are intermingled with the layers of coal. The suggestion that the flow was southwards is consistent with the theory of a northern land and a southern sea, and there is evidence that a subsidiary channel joins the main one from the north-west, near the Mary Pit.

It is hoped that the further extension of the channel will be traced as the coals are followed westwards in Kingseat, and north-eastwards towards Kinglassie, where Mr. Brown, mining engineer of the Fife Coal Co., has found evidence of a similar thinning.

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APPENDIX V

The 'Penlan Quartzite'

By E. E. L. Dixon, B.Sc., and J. Pringle

Plate I.

During the revision of the South Wales Coalfield several patches of plant-bearing quartzite, to which the name Penlan Quartzite was given, were found on the Old Red Sandstone outcrop near Kidwelly.[1] In this district the Carboniferous Limestone and Millstone Grit of the 'North Crop' of the coalfield are much displaced by a sheaf of strike-faults known as the Kidwelly disturbance. Owing to this fact and to the absence of good exposures, all that can be said with certainty of the relations of the quartzite is that west of the River Gwendraeth-fâch it rests almost, or quite, directly on the Senni Beds (Lower Old Red Sandstone). A patch west of Arles is represented on the geological map as dipping beneath the Lower Limestone Shales, but this relationship is inferred, not directly observed, and is now believed to be ill-founded. East of the river, where the Brownstones of the Old Red rest on the Senni Beds, the relations of the quartzite to these formations are quite uncertain.

The quartzite, which is best exposed in a line of outliers south-west of Pen-lan-uchaf and Pen-lan-isaf, is light or dark grey, tough, and fine-grained to conglomeratic. The included fragments are chiefly subangular, white quartzes up to 1·5 cm. long, with frequent flakes of grey shale indistinguishable from many Carboniferous shales, occasional red haematites ?, and small pink felspathic material Under the microscope the rock consists of quartz-grains showing marked strain-polarization, with rare felspars.

From the quartzite at various places the following plants have been identified by the late Dr. Kidston:—*Artisia approximata* (Brongn.), a Calamitic pith-cast, *Stigmaria ficoides* (Sternb.), and probably also its variety, *inaequalis* Göpp. A piece of silicified wood with its microscopic structure exquisitely preserved (*see* Pl. I) has also been examined by Kidston and is identified by Mr. J. Walton (*see* p. 126) as *Dadoxylon* cf. *materiarum* Dawson.

At the time of its discovery the quartzite was thought by one of us to belong, like the Senni Beds, to the Lower Old Red, but the plants were pronounced by Kidston[2] to negative this view, the greatest permissible age appearing at that time to be Upper Old Red Sandstone.

From the first it was recognised that lithologically the quartzite closely resembled the basal Millstone Grit as developed, for instance, at Mynydd-y-gareg, a mile or so away. The constituents, with the possible exception that haematitic fragments may be wanting from

[1] 'The Country around Carmarthen' (*Mem. Geol. Surv.*), 1909, pp. 68–70.
[2] See Carmarthen memoir, pp. 68–9.

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the Basal Grit, and their cementation are identical. In view of the character of the plants, Mr. Pringle maintained, when he collected the specimens, that the Penlan rock was nothing else but part of the Basal Grit in an abnormal position. Nowhere in South Wales is the latter formation known to rest on the Old Red, and at Mynydd-y-gareg it is separated therefrom by some 600 ft. of Avonian rocks.

Subsequently, on studying the problems of the Old Red Sandstone floras, Kidston came to the conclusion that the members of the flora of the 'Penlan Quartzite' are so highly organized that its age cannot reasonably be regarded as greater than Carboniferous. With this opinion Mr. Walton agrees.

The only Carboniferous formation that the 'Penlan Quartzite' resembles is the Basal Millstone Grit. Few plants except occasional *Stigmaria* have been recorded from the latter, but all those obtained from the 'Penlan Quartzite' might occur in it. In these circumstances the close lithological resemblance must be allowed full weight, and the conclusion that the 'Penlan Quartzite' is merely Basal Millstone Grit becomes inevitable. It remains to explain the position of the 'Penlan Quartzite' out on the Old Red outcrop.

The Kidwelly faulting belongs to the series of compressional disturbances that traverse South Wales, and it may, therefore, well include overthrusting. To account for the patches of Basal Grit at Penlan by overthrusting we must suppose that the plane of movement is of low hade, or, in places, even horizontal. Such overthrusts are not unknown in South Wales, a good example, seen in the cliffs of Pembrokeshire, having been described by Sir A. Strahan.[1] On the other hand the Penlan patches appear to be resting quite undisturbed on the Old Red, neither the quartzite a few feet above the junction nor the Senni Beds below, at a distance of a few yards horizontally from the junction, being shattered or distorted. Again, although the base of the Basal Grit is a plane of weakness and likely to become, under tangential pressure, a plane of movement, such a plane would not be expected to traverse one formation only along a strike of several miles. Overthrusting, therefore, though a possible explanation, is not supported by independent evidence.

At many places along the North Crop great masses of Basal Grit have sunk, owing to solution of the underlying Carboniferous Limestone, far below their normal position. But none has sunk through the Lower Limestone Shales on to the Old Red, and none of the tumbled masses of loose blocks resembles the flat, apparently undisturbed outliers at Penlan.

A more probable explanation of the occurrence of these outliers is to be found in the unconformity at the base of the Basal Grit, which has come to light in parts of South Wales and Monmouthshire since the survey of the Kidwelly district.[2] Near Abergavenny the

[1] In 'The Country around Haverfordwest' (*Mem. Geol. Surv.*), 1914, p. 168, pl. iii.

[2] Jones, O. T., in 'Summary of Progress' for 1906 (*Mem. Geol. Surv.*), 1907, p. 53; E. E. L. Dixon in 'The Country around Newport' (*Mem. Geol. Surv.*), edit. 2, 1909, p. 20, and *Geol. Mag.*, 1921, p. 157; and F. Dixey and T. F. Sibly, *Quart. Journ. Geol. Soc.*, vol. lxxiii, 1918, p. 111.

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Grit has transgressed the whole of the Carboniferous Limestone and rests directly on the Lower Limestone Shales. In fact, hereabouts it is transgressing so rapidly that, if it has maintained the same rate over the area from which it has since been denuded, it has formerly rested directly on the Old Red Sandstone at a short distance from its present escarpment at Blorenge.

The difficulty of this explanation is that, whereas near Abergavenny the transgression increases gradually for a distance of many miles, near Kidwelly a sudden increase must be assumed. On Mynydd-y-gareg, at a distance of only a mile from the nearest exposure of ' Penlan Quartzite,' resting on Senni Beds, the Basal Grit is underlain by high D-beds (horizon ϵ of Vaughan's original classification) and is separated from the Old Red Sandstone by about 600 ft. of Avonian rocks

Nevertheless we have proof that near Kidwelly another unconformity that shows little transgression along the outcrop to the north-east suddenly increases by several hundred feet. The unconformity is that between the base of the Avonian and the underlying Lower Old Red. Near Mynydd-y-gareg and for some miles to the north-east, the Avonian is separated from the Senni Beds by 500 ft. or more of Brownstones, whereas in the Gwendraeth-fâch, in the direction of Penlan and only 1½ miles from a normal development of Brownstones, it rests directly on the Senni Beds, overthrusting in this case being ruled out by the fact that the tight-welded junction has been actually observed. Both the exposure and Penlan are, however, separated from Mynydd-y-gareg by the Kidwelly disturbance. Presumably this Hercynian disturbance, which on the whole has a south-easterly downthrow, marked a line of weakness that had made itself felt with similar downthrow during the earth-movement between the Lower Old Red and the Avonian. If, as we believe, the ' Penlan Quartzite ' owes its position to transgression, the same line appears to have influenced (again with uplift to the north-west) the local intensity of the mid-Carboniferous movement.

Conclusions

1. The ' Penlan Quartzite ' is removed from the Upper Old Red Sandstone to the Carboniferous on account of its flora.

2. The only Carboniferous formation with which it can be correlated is the Basal Millstone Grit.

3. It owes its position, directly above Old Red Sandstone, to a local rapid increase of the mid-Carboniferous unconformity.

4. This rapid increase may be due to the influence, during the mid-Carboniferous earth-movement, of the line of weakness marked at a later date by the Kidwelly disturbance.

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NOTE ON *Dadoxylon* cf. *materiarum* DAWSON, FROM THE 'PENLAN QUARTZITE'

By J. WALTON, M.A.

Blocks of silicified wood consisting of well preserved secondary xylem were found in quartzite 80 yds. west of 8th milestone on Carmarthen road, 1¼ miles north-north-east of Kidwelly Church. No primary tissues are represented. The wood is of very uniform texture but there is a faint suggestion of periodic zones when a transverse section is viewed with the naked eye. The differences in structure which produce this effect cannot, however, be detected under the microscope.

The wood consists of tracheids and medullary ray parenchyma. There are occasional septate tracheids. The tracheids as seen in radial section of the wood (Pl. I, Fig. 2) average 51μ wide (Max. 86μ). In transverse section they are seen to be arranged in radial files which are about 5·3 times as numerous as the uniseriate medullary rays (Figs. 1 and 4). The tracheids are somewhat rectangular in transverse section.

The medullary rays are narrow. In radial section they are seen to be 1 to 20 cells in height, the individual cells being on the average about 25μ high and 75μ in a radial direction. The medullary ray cells are probably unpitted; the faint suggestion of pitting seen in the field being possibly due to the pits on underlying tracheids. The pits on the tracheids are confined to the radial walls and form from 1 to 5 rows of alternating bordered pits. The pits appear to be mutually flattened (Fig. 2) with oblique slit-like pores (Fig. 3). When both sides of the bordered pit are seen simultaneously, the pores are seen to have their long axes at right angles giving the appearance of a small cross (Fig. 3).

The structure of this wood is of a type widely spread in the Palaeozoic, more particularly in Permian and Carboniferous times. It bears the closest resemblance to *Dadoxylon materiarum* Dawson[1], but in the absence of the primary tissues, and from the fact that there are some minor dissimilarities, it is assigned tentatively to that species, which has so far been recorded only from Carboniferous rocks.

Explanation of Plate.

FIG. 1.—*Dadoxylon* cf. *materiarum* Daws. Slide PB 71. Transverse section × 145.

FIG. 2.—*Dadoxylon* cf. *materiarum* Daws. Slide PB 72. Radial section × 145.

FIG. 3.—*Dadoxylon* cf. *materiarum* Daws. Slide PB 72. Radial section × 300.

FIG. 4.—*Dadoxylon* cf. *materiarum* Daws. Slide PB 73. Tangential section × 145.

The slides are preserved in the Palaeobotanical collection of the Geological Survey, London.

[1] Penhallow, *Trans. Roy. Soc. Canada*, Sect. IV, 1900, p. 69; and Seward, Fossil Plants,' III, p. 256.

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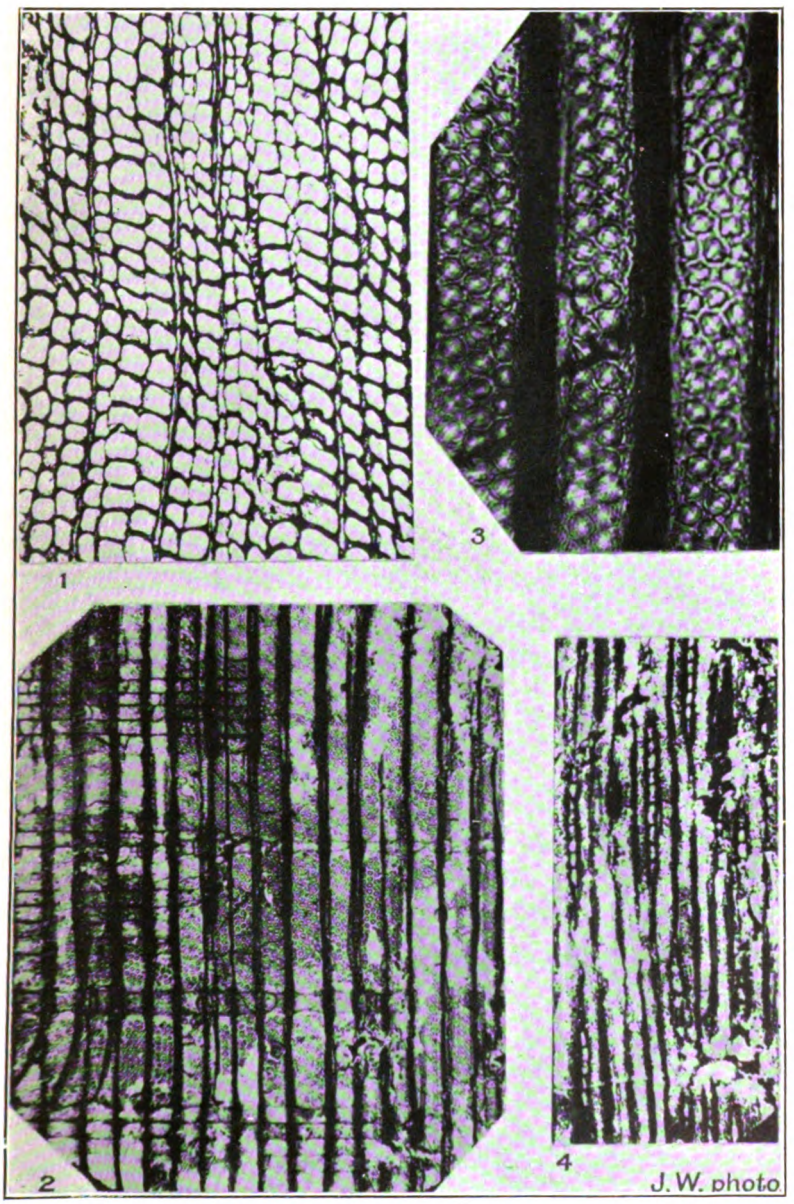

Dadoxylon cf. *materiarum* DAWSON.

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APPENDIX VI

The Barnsley Coal and its variations

By D. A. Wray, M.Sc.

Text-figures 1, 2, 3.

The Barnsley or Top Hard Coal is one of the most important and valuable seams of coal in the York, Derby, and Nottingham coalfield. Over the greater part of the area in which it has been mined it so far exceeds, both in thickness and value, any other known seam, that the development of the concealed coalfield to the east and south-east is very largely governed by the possibility of the uniform extension of this seam of coal in those directions. The total area over which the Barnsley Coal has already been proved exceeds six hundred square miles.

The Barnsley or Top Hard seam mainly owes its high economic value to the presence of a band of hard semi-anthracite coal, commercially termed 'Hards,' which characterises the seam wherever it is typically developed. This layer, varying from 2 to 3 ft. in thickness, consists of dull anthracite bands alternating with very thin brighter bituminous layers, and furnishes a high grade furnace and steam coal. Its relatively high carbon percentage ensures great heating power, while the presence of the thin bituminous layers renders it less difficult to ignite than pure anthracite. This particular band is consequently in considerable demand for a great variety of industrial purposes and is exported in large quantities from the Humber and East Coast ports to the Continent. It is the presence of this thin seam of 'Hards' which has very largely encouraged the extensive modern colliery developments in the concealed coalfield of South Yorkshire and Nottinghamshire.

The 'Hards' frequently, though by no means invariably, occur in the middle of the seam; the remainder of the coal termed top or bottom 'softs' yields valuable household, manufacturing, and occasionally good gas coals.

From the immediate south of Leeds the outcrop of the Barnsley Bed or its local representative can be traced continuously southwards across the coalfield to the vicinity of Nottingham; while in an easterly direction it can be followed under a gradually increasing cover of higher measures and newer formations, being everywhere represented in the numerous sinkings and borings in the concealed coalfield.[1]

In general the seam maintains a uniform character over the whole area south of a west and east line extending approximately

[1] For full details see Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 382–395. Wilson, G. V., 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 2nd edit., 1926, pp. 19-28.

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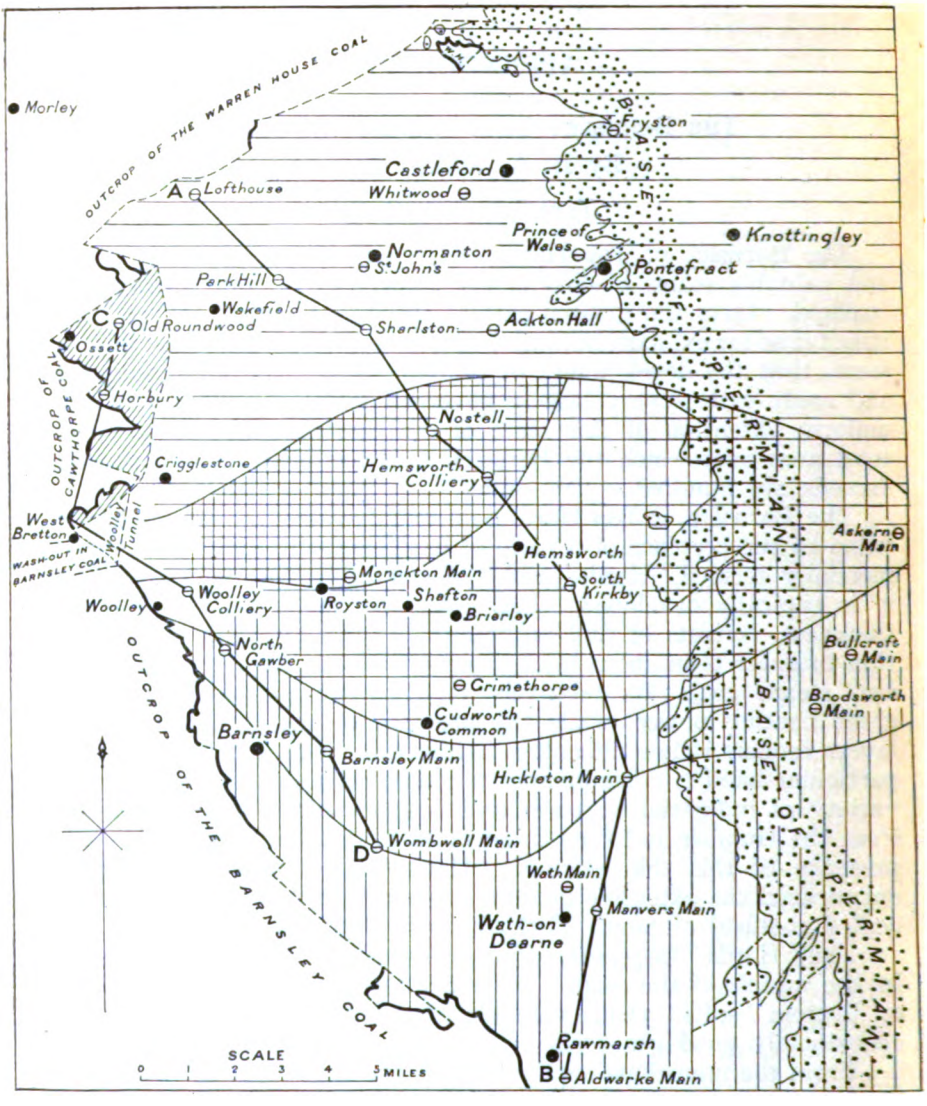

FIG. 1.—*Map of the Northern Part of the Yorkshire Coalfield illustrating the Variations in the Barnsley Coal.*

A B.—Line of Sections shown in Fig. 2.
C D.—Line of Sections shown in Fig. 3.

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through Woolley, Royston, Hemsworth and Askern; though local variations occur. In Nottinghamshire its thickness varies from 2 to 6 ft., while in South Yorkshire it is somewhat thicker, attaining its maximum development in the vicinity of Barnsley itself, where it is 9 ft. thick.

South of the above mentioned line the coal maintains what may well be termed the true Barnsley character or 'facies.' It consists normally of Top Softs, Hards, and Bottom Softs, with occasional thin or quite insignificant dirt or shaly partings. Slight differences in the nature of the Top or Bottom Softs give rise to purely local commercial terms which are applied to variations or subdivisions of these bands. The 'Hards' very generally though not invariably constitute the middle portion of the seam.

North of the Woolley-Askern line, however, the Barnsley seam is represented under two very different characters or 'facies.' These are known respectively as the Gawthorpe and the Warren House coals or 'facies.'

The Gawthorpe Coal, so named from the village of Gawthorpe near Ossett, has been mined around Horbury and Ossett, west of Wakefield, and consists of a seam of bituminous coal, devoid of any 'hards' and averaging 3 ft. in thickness.

The Warren House Coal has been extensively mined around Normanton and Castleford, and is characterised by its extreme variability; it consists of an alternation of thin coals and shale partings ranging from 4 to 20 ft. in thickness. Immediately to the east of Wakefield it is so split up with dirt partings as to be practically worthless. Further eastwards, however, towards Castleford it shows considerable improvement, the dirt partings becoming less frequent and generally thinner, and the characteristic band of 'hards' coming in to the extreme east, though only in a considerably attenuated form. In this area, however, it is always an inferior seam to the true Barnsley Bed.

The three 'facies' or varieties, the Barnsley, Gawthorpe, and Warren House coals have been clearly shown by the late Professor Green to be strictly correlative. This conclusion has been unequivocally endorsed by all subsequent observers who have investigated these coals or their associated measures. On the exact nature of the origin of these different 'facies,' however, two very diverse explanations have been offered. According to Green the numerous dirt partings which characterise the northern facies indicate "probably the site of a ridge of rising ground that lay between the two swamps in which the two coals grew."[1] On the other hand Professor Kendall, who has made a detailed study of the nature of the dirt partings in the Middleton Main Coal,[2] suggests that in the case of the Barnsley seam differential subsidence rather

[1] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 384.

[2] Kendall, P. F., 'On the Splitting of coal-seams by partings of dirt,' *Trans. Inst. Min. Eng.*, vol. liv, 1918, pp. 460–479.

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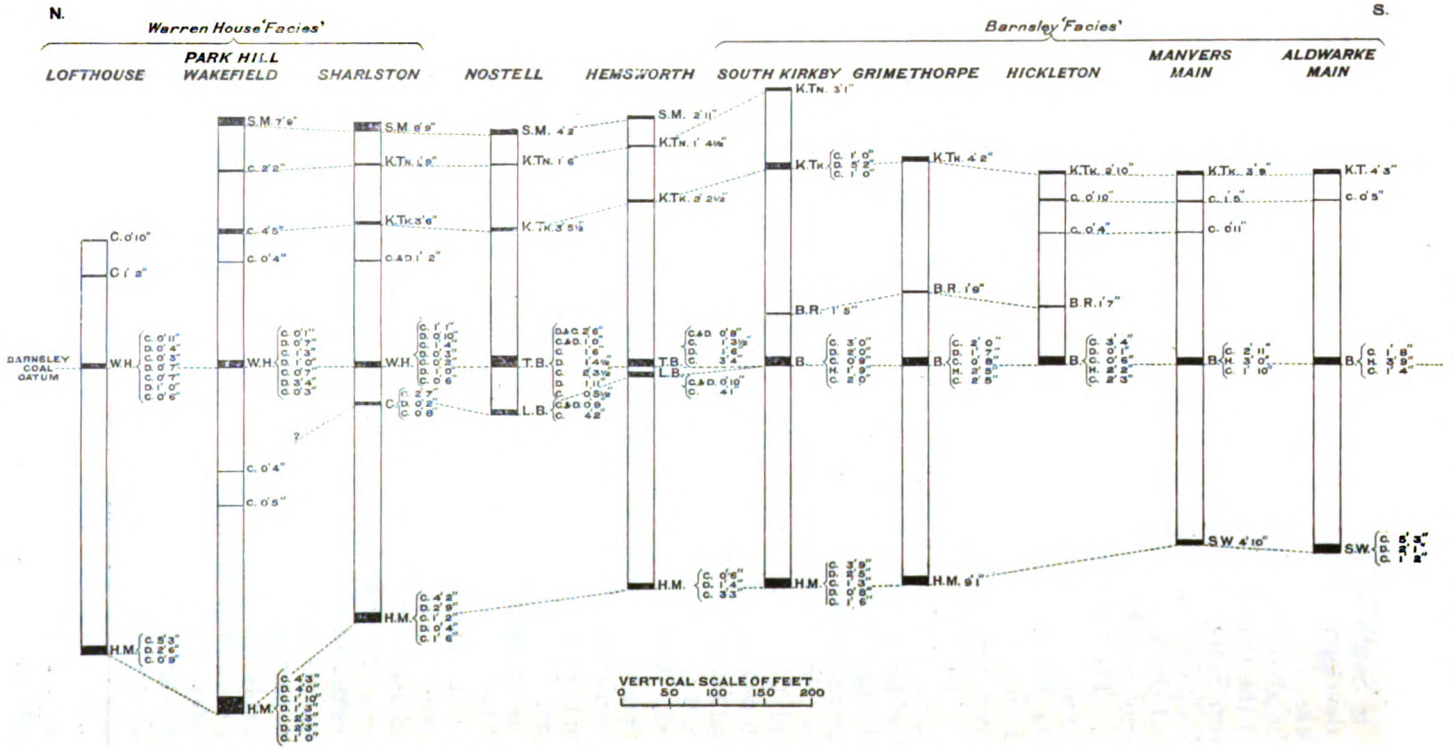

FIG. 2.—*Shaft Sections illustrating the Variations in the Barnsley Coal and its Relationship to other Coals.*

Abbreviations—B. Barnsley Coal.
T.B. Upper Barnsley Bed.
L.B. Lower Barnsley Bed.
W.H. Warren House Coal.
B.R. Barnsley Rider Coal.
S.M. Stanley Main Coal.
K.Tn. Kents' Thin Coal.
K.Tk. Kents' Thick Coal.
H.M., S.W. Haigh Moor, and Swallow Wood Coals.
C. Coal.
D. Dirt parting.
H. Hards.

N.B.—Grimethorpe Shaft lies somewhat to the west of the line of section **A B** in Fig. **1.**

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than elevation was the determining factor. According to Professor Kendall the seam "did not die a dry death but was drowned."[1]

During the resurvey of the area to the south and west of Wakefield several observations have been made which appear to have a bearing on this interesting problem, and these are briefly summarized and correlated with the already known facts below.

In order to illustrate in a concise manner the gradual change which occurs in the Barnsley Bed or its representatives as traced from south to north, Fig. 2 represents a series of shaft sections or sinkings extending from Aldwarke Main, near Rotherham, to Lofthouse, near Leeds, a total distance of about twenty-two miles. The southern sections occur in the central portion of the South Yorkshire coalfield, while the more northerly extend across what is usually known as the West Yorkshire coalfield. In the former the Barnsley Bed is typically developed, while in the northern sections the coal is in the Warren House facies.

At Aldwarke Main the following is an average section of the Barnsley Bed :—

	Ft.	In.
Top Softs	1	8
Hards	3	9
Bottom Softs	1	4

In this district a distinct band termed Roof coal or 'Baggs,' 1 ft. to 1 ft. 6 in. thick, may also occur above the Top Softs. While, however, the above represents an average section, considerable variations in the beds themselves are met with in the Rotherham district.

Four miles to the north the following is the average section at Manvers Main and Wath Main collieries :—

	Ft.	In.
Baggs Coal	1	1
Top Softs	1	2
Clay Coal	0	8
Hards	2 ft. 6 in. to 3 ft. 3 in.	
Bottom Softs or Slotting Coal	1	10

In this area the coal is somewhat thinner as a whole; the 'Hards' showing attenuation, while the 'clay seam,' an inferior and impure band, makes its appearance. Still further to the north, at Hickleton Main, a dirt parting one inch thick appears in the middle of the 'clay seam,' the average section hereabouts being as follows :—

	Ft.	In.
Baggs Coal	1	0
Top Softs	1	1
Upper Clay Coal	1	3
Dirt Parting	0	1
Lower Clay Coal	0	6
Hards	2	2
Bottom Softs	2	3

[1] Kendall, P. F., and H. Wroot, 'Geology of Yorkshire,' 1924, pp. 150–152.

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To the north of Hickleton the Barnsley Bed has been extensively mined around Grimethorpe, Frickley, South Kirkby, Hemsworth and Nostell. In all these workings the dirt parting is always present and gradually increases in thickness in a northerly direction until at Nostell the lower and upper portions of the Barnsley Bed are separated by as much as 53 ft. of barren strata. That the two Barnsley coals at Nostell are the upper and lower portions of the one seam to the south is clear from the practically continuous workings extending between Hickleton and Nostell.

In the South Kirkby district the thickness of the dirt parting ranges from 1 ft. to 2 ft. 3 in., the general increase being most rapid in a north-westerly direction. At Cudworth Common, however, the dirt parting was found to be only 2 to 3 in. thick, while at Grimethorpe Colliery it ranges from 1 ft. 7 in. to 1 ft. 8 in. in thickness. Half a mile to the north it averages 2 to 3 ft., while around Brierley, one mile to the north of Grimethorpe Colliery, it is not more than 1 ft. 6 in. thick. Around Shafton its average thickness is not more than 3 ft., but north of that it rapidly increases in importance and the two beds of coal are mined separately. In the more easterly portions of Monckton Main Colliery workings the dirt parting is 5 ft. thick, while, when traced north and west, it increases rapidly to 30 ft. in thickness. In the most northerly workings of these collieries the two seams are 45 ft. apart; the Top Softs being 4 ft. 2 in. thick, while the Bottom Softs, with a much attenuated band of 'Hards,' averages 4 ft. in thickness. The change is less rapid between Grimethorpe and Hemsworth. At the latter colliery the parting is about 7 ft. thick, but between here and Nostell it suddenly swells out to over 50 ft. At Nostell, however, the two component portions of the original Barnsley Bed begin to take in numerous dirt partings, and at Sharlston the true 'Warren House facies' is represented, the thin layer of 'Hards' having disappeared. In the area to the north the seam generally worked and called the Warren House Coal appears to be the upper part of the Barnsley Bed; the lower part becoming so split up with shale partings as to render its exploitation unprofitable. At St. John's Colliery, near Normanton, the Warren House seam was found to be 22 ft. thick, and to contain no less than eight shale partings, the thickest individual seam of coal being under 2 ft.

In the eastern area, however, around Castleford and Pontefract, there is an approach to conditions under which the Barnsley seams around Nostell and Hemsworth were deposited. Thus, at the Prince of Wales Colliery, Pontefract, the two seams are 16 ft. apart, while at Ackton Hall, where the parting between the two seams ranges from 10 to 15 ft. in thickness, the lower seam contains an 8-in. band of 'Hards.'

A closer investigation of the dirt parting in the Barnsley seam in the area between Hemsworth and Hickleton has revealed some striking features; and one of the most significant is the manner in which the variations in thickness are influenced by faulting.

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In the numerous coal workings around Royston, Hemsworth, Brierley, and South Kirkby, several prominent faults which trend in a north-east and south-west direction have been encountered and those with a considerable throw have been adopted as the boundary between the several companies' workings. Across these faults there is invariably an abrupt variation in the thickness of the dirt parting. In the case of one with a small throw to the north, the dirt parting is practically absent on the immediate south side of the fault plane. The majority, however, have a downthrow to the south-east; in these cases there is a local thickening on the south side of the fault. As followed south-east, the parting thins rapidly and is more uniform in thickness. It is also significant that although the dirt parting shows such variations, the coals themselves show no clear evidence of any such abrupt change across the faulted area; the change in the nature of the seam being of a more regular regional character.

It seems clear, therefore, that these faults were actually in operation during the formation of this composite seam; and further, that the actual period of movement was very largely, if not entirely confined to the interval represented by the deposition of the measures between the upper and lower portions of the Barnsley Bed.

The relationship of the Gawthorpe Coal to the typical Barnsley seam is illustrated in Fig. 3, which shows a series of sinkings and sections from Wombwell and Barnsley in the south-east to the neighbourhood of Ossett in the north-west.

At Barnsley and Wombwell the Barnsley Bed consists respectively of Tops and Bottom Softs, with an intervening band of 'Hards'; a thin parting of dirt also occurs, which becomes more pronounced as the seam is traced northwards.

At North Gawber the dirt parting is 11 in. thick and contains a 7-in. seam of coal.

Throughout this area a thin seam of coal locally known as the Barnsley Rider, which occurs from 70 to 80 ft. above the Barnsley Bed, is invariably present. It is readily distinguished by the thin layer of brassy or pyritous coal, 6 in. thick, which overlies it. At Woolley Colliery the Barnsley Rider occurs 70 ft. above the Barnsley Seam; the latter contains four distinct shale partings, though the band of 'Hards' is still well developed, being 2 ft. 6 in. thick. Within a mile to the north-west, however, it undergoes very rapid changes; the 'Hards' disappear entirely, and a dirt parting 15 in. thick at Woolley Colliery, swells out to over 20 ft. in thickness, the Barnsley Bed being split up into an upper and lower bed. Here also the Barnsley Rider Coal occurs within 45 ft. of the underlying Barnsley Bed. An excellent open section of the measures at this horizon occurs at the southern end of Woolley Edge Tunnel, a little over 2,000 yds. north-west of the Woolley Colliery shaft. The Barnsley Rider Coal is well exposed just above the roof of the tunnel and shows a corresponding section to that revealed in the shaft sections to the south. The Barnsley seam itself is entirely obscured, though a

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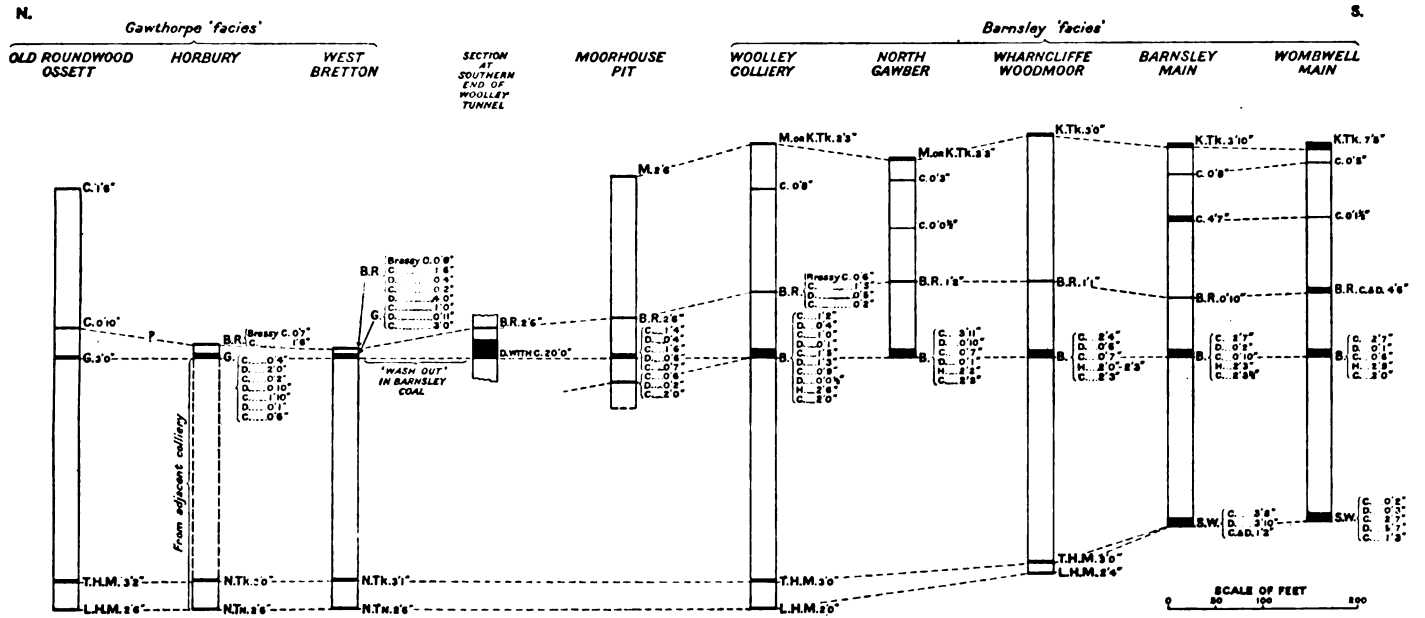

FIG. 3.—*Shaft and other Sections illustrating the Variations in the Barnsley Coal and its Relationship to other Coals.*

Abbreviations—B. Barnsley Coal.
G. Gawthorpe Coal.
B.R. Barnsley Rider Coal.
K.Tk.,M. Kents' Thick or Mapplewell Coal.
S.W. Swallow Wood or Haigh Moor Coal.
T.H.M., N.Tk. Top Haigh Moor or Netherton Thick Coal.
L.H.M., N.Tn. Low Haigh Moor or Netherton Thin Coal.
C. Coal.
D. Dirt parting.
H. Hards.

N.B.—Wharncliffe Woodmoor Shaft lies somewhat to the east of the line of section C D in Fig. 1.

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measured section of the cutting, kindly furnished by the Railway Company, shows about 20 ft. of shale with numerous thin bands of coal and coaly shale on this horizon.

Between here and the village of West Bretton, nearly a mile to the north-west, the Barnsley Coal is entirely wanting. Several trials have been made in this area on behalf of Messrs. Stringer & Co. of Clayton West Collieries, and though the Barnsley Rider Coal can be continuously traced, and exhibits its characteristic features, no coal whatever intervenes between it and the underlying Netherton Thick Coal. It is of further interest to note that this area corresponds with an extensive ' wash-out ' in the Barnsley Coal workings to the east.

At Brick Bank, West Bretton, however, the following section is exposed :—

		Ft.	In.
	Black Shale		
Barnsley Rider Coal	Brassy Coal	0	6
	Coal	1	6
	Dirt	0	4
	Coal	0	2
	Yellow Clay	4	0
Gawthorpe or Barnsley Bed	Coal	1	0
	Dirt	0	11
	Coal	3	0
	Fireclay		

Immediately to the north the coal has recently been extensively mined along the outcrop and maintains the above features ; and from thence the outcrop of the Gawthorpe Coal can be traced more or less continuously across the Calder valley to Horbury and Ossett.

An excellent section of the measures on this horizon was examined and measured by the writer in company with Mr. Bromehead along the new railway widening at Horbury Junction in the summer of 1924. The Gawthorpe Coal hereabouts approaches the Warren House ' facies,' containing numerous shale partings. Fifteen feet above it, and separated from it by bluish grey shaly mudstones with bands of ironstone nodules, occurs the local representative of the Barnsley Rider Coal. It consists of 18 in. of inferior coal overlain by 7 in. of brassy and shaly coal.[1]

The Gawthorpe Coal has been worked at Low Laithes and Old Roundwood Collieries, Ossett, and averages from 3 ft. to 3 ft. 6 in. in thickness.

The variations in the character of the Barnsley Bed as traced northwards are clearly the result of varying conditions of deposition. The entire seam of coal or group of coals was probably laid down in a deltaic area which was undergoing subsidence, and local inequalities in the rate of subsidence are, it is generally agreed, the underlying

[1] A measured section is given by Professor Green, ' Geology of the Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1878, p. 391. Professor Green's section shows considerable divergence from ours. He does not record the Rider Coal which here overlies it. See, however, page 767 of the above memoir.

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causes of these variations. The several coal-seams such as the Silkstone, Parkgate, or Barnsley coals, by their persistence over very wide areas, furnish valuable indices as to the relative rate of subsidence taking place in any area in the interval between their deposition; for if they are truly continuous from end to end, and strictly contemporaneous in origin, they must have accumulated upon a level or nearly level surface. Consequently a relatively thickening in the interval between any two such well-marked horizons furnishes an index of a relatively more rapid rate of subsidence. It was by the application of this principle that Professor Kendall maintained that the Warren House Coal was deposited in a more rapidly subsiding area than the true Barnsley seam.[1] This is clearly shown in Figs. 2 and 3, where the interval between the Barnsley Coal and the underlying Haigh Moor or Swallow Wood Coal increases northwards in close correspondence with the change in the character of the Barnsley seam and its northern representative, the Warren House Coal.

It is of further interest to note that several of the important coal seams in the Yorkshire Coalfield change in a somewhat similar manner when traced from south to north. Thus the Swallow Wood or Haigh Moor Coal splits into an upper and lower bed to the immediate north of Barnsley (Fig. 3). The interval, however, between the underlying Parkgate Coal and the Haigh Moor or Swallow Wood Coal decreases in a northerly direction. Thus, around Wombwell the Haigh Moor and Parkgate coals are 640 feet apart; around Barnsley 560 feet; at Woolley 465 feet; while around West Bretton the distance between the Lower Haigh Moor Coal and the Parkgate or Old Hards Coal is 435 feet. It would, therefore, appear that the splitting of the Haigh Moor coals has resulted from the opposite cause to that which operated in the case of the Barnsley Coal, and that its conditions of formation more closely approximate to those originally postulated by Green.[2]

The conditions that obtained during the deposition of the Barnsley Bed may now be briefly summarized as follows:—Coal formation took place over an extensive area, while north of the Woolley-Askern line the area sank more rapidly than to the south and was flooded with fine-grained sediment apparently coming mainly from a westerly source which allowed of only very intermittent coal-formation in the 'Normanton' basin. The general increase in the thickness of shale takes place towards the neighbourhood of Woolley itself and strongly suggests that a stream entered the Normanton basin from higher ground to the west, and passing south of West Bretton spread out its detritus north-eastwards, eastwards, and south-eastwards on the floor of the subsiding area.

During this period also, movement was taking place along the faults trending in a north-east and south-west direction around

[1] Kendall, P. F., and H. E. Wroot, 'The Geology of Yorkshire,' 1924, pp. 151–152.
[2] Green, A. H., 'The Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, pp. 242–243 and 390.

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Hemsworth and South Kirkby. It is of interest to note that these faults are parallel to the prominent Don Valley faults south of the present area, which Professor Fearnsides' researches have clearly shown to have been in operation during the deposition of the Coal Measures.

The final episode is the complete infilling of the Normanton basin with sediments, and the more or less uniform formation of coal over the entire area. The mode of origin of anthracitic layers in coal seams is still largely an unsolved problem. In the case of the band of ' Hards ' in the Barnsley seam the most favourable conditions were those where an undisturbed uniform formation of coal took place.

The conditions that prevailed subsequent to the deposition of the Barnsley Bed are clearly indicated by taking the thin but persistent Barnsley Rider Coal as an index. Around Barnsley, Wombwell and Gawber it occurs 70 to 80 ft. above the Barnsley Bed but when followed to the north of Woolley the interval between the Barnsley Rider and Barnsley coals decreases until at West Bretton only four feet of clay separates them. Further north again, at Horbury, they are 15 ft. apart, and at Ossett 35 ft. Depression to the south of the Woolley district must therefore have subsequently taken place, and to a lesser degree in a northerly direction ; or what seems more probable, a small uplift of very wide amplitude took place, the axis of which lay somewhere in the vicinity of Woolley. The interval between the Barnsley Rider Coal and the succeeding seam, the Kents Thick or Mapplewell, is very uniform over the entire area ; in other words, the variation in the distance between the Barnsley and Kents Thick coals is almost exactly represented by the interval between the Barnsley and Barnsley Rider coals. Uniform subsidence of the entire area, therefore, seems to have followed the deposition of the Barnsley Rider Coal.

In the resurvey of the district to the west of the area described above, considerable information about the underlying measures has been collected ; a full account of these will be given in the forthcoming memoir on that district. One of the most striking features that has been met with, however, is the occurrence of a corresponding line or zone extending from Thurstonland to High Hoyland in apparent continuation of the Woolley-Askern line described above. During the formation of the lower measures it appears to have frequently separated two distinct areas of deposition ; and in the Lower Coal Measures there are evidences of frequent and slight movements of uplift along this axis. Such a line as that referred to above readily forms a natural boundary between the so-called West and South Yorkshire coalfields ; and though of apparently slight tectonic importance, it appears to have had a very profound and far-reaching effect on the nature of the several coal-seams these measures contain.

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APPENDIX VII

The Eastern Boundary of the Concealed Coalfield of Yorkshire and Nottinghamshire

By G. V. Wilson, B.Sc.

The recent borings at Sutton and Doddington, of which descriptions are given below, have added considerably to our knowledge of the character and distribution of the Coal Measures in eastern Nottinghamshire and Lincolnshire. Through the courtesy of the various parties concerned we were given free access to the cores for the purpose of examination and collection of specimens. Those at Sutton have been systematically broken up and searched by Mr. A. Templeman.

The details of the sections are as follows.

Sutton Boring

One-inch Sheet (N.S.) 101; six-inch Map Notts. 9 N.E.

Communicated by Mr. A. R. Thomlinson.

Height above O.D. about 45 ft.

(Slightly abridged.)

	Thickness		Depth	
SURFACE	Ft.	In.	Ft.	In.
Soil	1	4	1	4
Clay, sand and gravel	23	0	**24**	**4**
TRIAS (*Bunter Sandstones*)				
Red sandstone	59	4	83	8
Red sandstone with pebbles	4	4	88	0
Coarse red sandstone	76	1	164	1
Soft red sandstone	173	2	337	3
Red marly sandstone with pebbles	164	0	501	3
Red marly sandstone with marl pebbles	19	7	520	10
Red marly sandstone	31	6	552	4
Red and grey sandstones	45	5	597	9
Red and grey marls	34	11	**632**	**8**
PERMIAN (*Upper Magnesian Limestone*)				
Hard reddish limy sandstone	7	5	640	1
Strong blue and red marl	2	0	642	1
Hard reddish limy sandstone	4	5	646	6
Hard grey limestone	31	2	**677**	**8**
(*Middle Marls*)				
Brown and grey sandy marls with gypsum	119	8	797	4
Brown sandy marl, grey sandstone, gypsum	26	9	824	1
Grey rock with gypsum, brown sandy marl	12	9	836	10
Blue sandy marl	1	2	**838**	**0**
(*Lower Magnesian Limestone*)				
Grey limestone	51	3	889	3
Grey limestone with bands of shale	85	2	974	5
Grey shale, limestone bands	70	8	1045	1
Grey limestone with bands of shale	38	10	1083	11
Grey shale (Marl Slates)	7	8	1091	7
Breccia, fine grained, small pebbles	5	3	**1096**	**10**

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COAL MEASURES (*Middle*)	Thickness Ft.	In.	Depth Ft.	In.
Red and blue sandy marl and shale	17	2	1114	0
Red, blue and mottled shale	13	9	1127	9
Greenish, blue and mottled shales	30	8	1158	5
Fireclay	3	3	1161	8
Greenish, blue, red and mottled shales	37	8	1199	4
Soft grey micaceous sandstone	24	1	1223	5
Grey shale	12	5	1235	10
Coal (bastard cannel)	**0**	**8**	**1236**	**6**
Fireclay	1	8	1238	2
Sandstone	8	7	1246	9
Soft brown marl	4	4	1251	1
Sandstone	26	10	1277	11
Brown mottled marl	2	0	1279	11
Blue and grey sandstone	74	8	1354	7
Fireclay	0	7	1355	2
Dark shale	11	8	1366	10
Grey sandstone	9	0	1375	10
Blue shale	25	7	1401	5
Coal	**1**	**10**	**1403**	**3**
Sandy fireclay	4	9	1408	0
Rooty shale (clunch)	15	8	1423	8
Sandstone and sandy shale	13	9	1437	5
Black and grey shale	116	8	1554	1
Sandstone and sandy shale	29	7	1583	8
Black shale, clunch with ironstone nodules	9	10	1593	6
Sandstone and sandy shale	51	6	1645	0
Sandy shale } TOP MARINE BED {	3	11	1648	11
Black shale } TOP MARINE BED {	6	1	**1655**	**0**
Black shale	4	9	1659	9
Grey sandstone	11	0	1670	9
Sandstone and sandy shale	15	11	1686	8
Dark shale	21	4	1708	0
Grey shale (MARINE BED)	7	6	**1715**	**6**
Fireclay (clunch)	10	0	1725	6
Black shale	5	6	1731	0
Grey shale and sandy shale	8	2	1739	2
Sandstone	126	8	1865	10
Grey and dark shale	37	6	1903	4
Clunch	8	4	1911	8
Sandy shale and sandstone	12	7	1924	3
Grey shale and sandstone	45	3	1969	6
Grey and black shale, fireclay, sandstone	26	3	1995	9
Grey shale, sandy shale and clunch	35	9	2031	6
Coal	**0**	**2**	**2031**	**8**
Dark shale	0	5	2032	1
Coal	**0**	**3**	**2032**	**4**
Grey shale and sandstone	25	11	2058	3
Black and blue shale	5	10	2064	1
Blue shale with ironstone bands } MANSFIELD MARINE BED {	32	3	2096	4
Dark grey shale } MANSFIELD MARINE BED {	2	4	2098	8
Cank } MANSFIELD MARINE BED {	0	4	2099	0
Dark grey shale } MANSFIELD MARINE BED {	0	6	**2099**	**6**
Coal	**0**	**2**	**2099**	**8**
Clunch	10	11	2110	7
Shale with ironstone, fireclay	12	10	2123	5
Black shale (MARINE BED at 2127 ft.)	4	11	**2128**	**4**
Coal	**0**	**1**	**2128**	**5**
Grey shale and clunch with ironstone	21	7	2150	0

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	Thickness Ft.	In.	Depth Ft.	In.
Grey shale (MARINE BED)	20	5	**2170**	**5**
Clunch, shale, sandstone and sandy shale ..	14	5	2184	10
Black shale	9	0	2193	10
Grey sandstone, shale and clunch	27	4	2221	2
Black shale	7	6	2228	8
Coal	**2**	**7**	**2231**	**3**
Fireclay	4	10	2236	1
Grey shale and sandstone	17	9	2253	10
Black shale with ironstone bands	**3**	1	2256	11
Clunch	11	0	2267	11
Grey sandy shale	7	0	2274	11
Clunch	**3**	7	2278	6
Grey shale	16	11	2295	5
Sandstone and grey shale	16	7	2312	0
Black shale	6	6	2318	6
Coal	**1**	**10½**	**2320**	**4½**
Fireclay and sandstone	5	8½	2326	1
Grey shale with ironstone bands	10	1	2336	2
Black shale with ironstone bands	**3**	11	2340	1
Grey shale, sandstone and sandy shale ..	**44**	1	2384	2
Black and grey shales	49	6	2433	8
Grey shale and grey sandy shale	60	7	2494	3
Black shale and clunch	16	2	2510	5
Grey shale and black shale	25	2	2535	7
Coal	**0**	**2½**	**2535**	**9½**
Grey and black shales	17	4½	2553	2
Sandstone and sandy shale	39	5	2592	7
Black shale	3	10	2596	5
Sandstone	1	7	2598	0
Clunch and coal strings	10	8	2608	8
Grey sandy shale and sandstone, current-bedded	49	4	2658	0
Sandstone	5	10	2663	10
Sandy shale	3	5	2667	3
Black shale with ironstone bands	10	2½	2677	5½
Coal (TOP HARD)	**4**	**9½**	**2682**	**3**
Clunch with ironstone nodules	9	1	2691	4
Coal	**0**	**10**	**2692**	**2**
Hard sandy shale	5	9	2697	11
Black shale	3	3	2701	2
Grey shale and sandy shale	8	8	2709	10
Coal with dirt partings (? DUNSIL) ..	**1**	**1½**	**2710**	**11½**
Clunch with ironstone nodules	7	1½	2718	1
Sandstone and sandy shale	15	5	2733	6
Black shale with ironstone nodules	4	10	2738	4

This boring was put down by the Foraky Co. for Messrs. James Nimmo & Co., Ltd. The diameter of the hole at the top was 17 in. and that of the cores 7 in. at a depth of 1800 ft. and at the bottom 4¼ in. A complete core of the Top Hard Coal was obtained 4¼ in. in diameter, from a depth of 2,682 ft. by means of the double core-barrel. The chilled shot process was used for the Permian and Trias excepting for about 120 ft. of the Lower Magnesian Limestone which was percussion drilled. The diamond crown was employed for the whole of the Coal Measures, and the double core-barrel was used in proving a few of the other coal seams besides the Top Hard.

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The Top Marine bed was encountered at a depth of 1,645 ft. It is about 10 ft. thick and occurs 444 ft. above the Mansfield Marine Bed, as compared with 518 ft. at Checkerhouse and 369 ft. at Hayton Smeathe. A bed of grey shale at 1,708–1,715 ft. was noted by Mr. A. Templeman to yield *Sanguinolites* probably undescribed, and *Lingula mytiloides*, and so may be regarded as being of marine origin. As at Checkerhouse and Hayton Smeathe a thick mass of sandstone and sandy shale occurs between the Top Marine Bed and the Mansfield Marine Bed, though it is of a grey colour and not stained red and purple as at those localities. The Mansfield Marine Bed with its characteristic fauna was found between 2,064 ft. and 2,099 ft. It contains about 4 in. of poorly developed 'cank' near the base. *Lingula* and *Orbiculoidea* are recorded by Mr. Templeman from a bed of black shale at 2,127 ft. A bed of grey shale which yielded a few marine fossils occurs between 2,150 and 2,170 ft. It shows the same lithological characters, and scarcity of fossils that distinguish a bed in about the same position at Haughton boring, and Ollerton sinking.

The Mansfield and the Top Marine Beds occur at the top of bands of sediment, which are about 80 ft. thick and have another marine bed at the base. An intermediate marine bed also occurs about 30 ft. below the Mansfield Marine Bed. Beds with marine shells were noticed by Culpin and Dyson at Bentley and Maltby 87 ft. and 145 ft. respectively below the Mansfield Marine Bed.[1] A marine horizon has also been noted in about the same position at Armthorpe, Haughton and Ollerton. At Armthorpe *Lingula* has also been found in a bed lying about 150 ft. below the Top Marine Bed. It would appear, therefore, that the Coal Measures land surface was oscillating at about sea-level for a considerable period previous to the deposition of both the Mansfield and Top Marine Beds, and that each represents an important and fairly wide incursion of the sea during Coal Measures times.

As at Haughton no coal was noted, with either *Lingula* or other marine shells in the roof shales, that could be assigned to the position of the Abdy Coal.

An excellent Top Hard Coal 4 ft. 9½ in. thick was proved at a depth of 2,682 ft. An interesting feature was that the roof consisted of about one inch of cannel.

The boring was taken down to a depth of 3,552 ft. No signs of faulting were noted above the undoubted Top Hard Seam. A black shale with *Lingula* occurs between the depths of 2,904 and 2,907 ft. It is considered to represent the marine bed which in other parts of the coalfield occurs some 200–300 ft. above the Deep Hard Coal.

A list of fossils collected by Mr. Templeman is given below, and the figures following each name represent the depths in feet from which the specimens were obtained. The plants have been named by Mr. John Walton, M.A., while a selection of the fresh-water

[1] Culpin, H., 'Marine and other fossils in the Yorkshire Coal Measures, etc. *Proc. Yorks. Geol. Soc.*, vol. XVI, pt. 111, 1908, p. 326; also Dyson, W. H., *Rep Brit. Assoc.* for 1910, 1911 Sheffield Meeting, p. 610.

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mollusca from the Coal Measures was submitted to Dr. A. E. Trueman. All of the new species mentioned in the list have been referred to forms, described by himself and Mr. J. H. Davies, in a paper not yet published. The remaining specimens have been determined by Mr. J. Pringle. (The figures refer to depths from which the specimens were taken.)

PERMIAN

Upper Magnesian Limestone

Mytilus *cf.* squamosus (*J. de C. Sow.*), 636.
,, sp., 636, 638.
Schizodus ?, 636.

Lower Magnesian Limestone

Plants, 1085.
Acanthocladia ?, 1072.
Lingula credneri (*Geinitz*), 1060, 1082.
Productus horridus (*J. de C. Sow.*), 1078.
Strophalosia morrisiana (*King*), 1072.
Schizodus ? 850.

COAL MEASURES

PLANTAE

Alethopteris decurrens (*Artis*), 2970.
,, lonchitica (*Schloth.*), 2284.
,, serli (*Brongn.*), 2285, 3324.
Dactylotheca plumosa (*Artis*), 2358.
Eupecopteris *cf.* volkmanni (*Sauveur*), 2532.
Mariopteris beneckei (*Huth*), 3536.
,, nervosa (*Brongn.*), 2446.
Neuropteris flexuosa (*Sternb.*), 3108.
,, gigantea (*Sternb.*), 3329.
,, *cf.* ,, 1730.
,, heterophylla (*Brongn.*), 1456, 2440, 2957, 3014, 3298, 3329.
,, obliqua (*Brongn.*), 3031.
,, pseudogigantea (*Potonié*), 2285.
,, *cf.* ,, 2526.
,, rarinervis (*Bunb.*), 3329.
,, *cf.* schützei (*Potonié*), 3318.
,, tenuifolia (*Schloth.*), 2533.
,, sp., 2747.
Calamites *cf.* undulatus (*Sternb.*), 3088.
,, sp., 2703.
Annularia microphylla (*Sauveur*), 2372.
,, *cf.* ,, 2533.
Asterophyllites longifolium (*Brongn.*), *forma* striata (*Weiss*), 2532, 2633.
,, sp., 2645.
Myriophyllites gracilis (*Artis*), 2285.
Sphenophyllum cuneifolium (*Sternb.*), 3031.
Bothrodendron minutifolium (*Boulay*), 2358.
Cf. ,, ,, 2526.
Lepidodendron *cf.* obovatum (*Sternb.*), 2717.
,, simile (*Kidston*), 1730, 2534.
,, sp., 2739, 3329.
Sigillaria ovata (*Sauveur*), 2534.
,, *cf.* ,, *var.* essenia (*Achepohl*), 2279.
,, sp., 2270.
Lycopod megaspores, 3217.
Cordaites sp., 2284, 2633.
Samaropsis fluitans (*Dawson*), 2270.

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ANIMALIA

(i) Fresh-water

Anthracomya *cf.* minima (*Hind*) [*pars*], 3452.
,, phillipsi (*Will.*), 1115.
,, *cf.* ,, 1115, 1138, 1380, 1435–8, 1474.
? ,, phillipsi (*Will.*), 1525, 1544, 1673.
,, pulchra (*Hind*), 2500.
,, *cf.* pumila (*Salter*), 2500.
,, *cf.* subcentralis (*Salter*), 2339.
,, sp. nov., 2548, 2736.
,, sp. nov., 1115.
,, sp. nov.?, 2755.
,, sp., 1435–8, 2254, 3437.
Carbonicola *cf.* acuta (*J. de C. Sow.*), 2736.
,, aquilina (*J. de C. Sow.*), 2225, 2103.
,, *cf.* ,, 2701, 2822.
,, *aff.* ,, 2396.
,, *cf.* similis (*Brown*), 2769.
,, sp. nov., 3453.
,, sp. nov., 3144, 3211.
,, sp. nov., 2385, 2396.
,, sp. nov., 2812, 2901.
,, sp. nov., 3185.
,, sp. nov., 3212.
,, sp., 2112, 2546–8, 2738, 2768, 2903, 3079, 3382.
Naiadites *cf.* carinata (*J. de C. Sow.*), 2736.
,, quadrata (*J. de C. Sow.*), 2738.
,, *cf.* ,, 2064, 2736, 2832.
,, *cf.* triangularis (*J. Sow.*), 2057, 2385, 2396, 2499, 2759, 2838.
,, sp., 1891, 2339, 2546.

(ii) Marine

Chonetes laguessiana (*de Kon.*), *mut. θ.* Hind., 2099.
Lingula mytiloides (*J. Sow.*), 1715, 2088–99, 2127, 2150–70, 2904, 2907.
,, *cf.* ,, 1645.
Orbiculoidea nitida (*Phill.*), 2088–99, 2127.
Ctenodonta undulata (*Phill.*), 2088–99.
Nuculana attenuata ? (*Flem.*), 2088–99, 2170.
Pterinopecten ?, 1655.
Sanguinolites sp. nov.?, 1708, 1713–1715.
,, ?, 2088–99.
Euphemus urei (*Flem.*), 2088–99.
Loxonema ?, 2092.

Goniatites, 2088–99.
Anthrapalaemon sp., 2957.
Prestwichia ?, 2150.

(iii) Fish remains

Coelacanthus ?, 2736, 3514.
Megalichthys sp., 2186.
Rhizodopsis sauroides (*Will.*), 2000, 2226, 2385.
,, sp., 2127, 2736.

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Doddington Boring

One-inch Sheet (N.S.) 114; six-inch Map, Notts. 21 N.E.

Communicated by Mr. J. Ford[1].

Height above O.D. 25 ft.

Summary of Journal

	Thickness Ft.	In.	Depth Ft.	In.
SURFACE: Sand, soil, clay and gravel	31	0	**31**	**0**
LIAS and RHAETIC: Blue clay and marl ..	154	0	**185**	**0**
TRIAS (*Keuper Marls*) with gypsum	988	0	1173	0
(*Bunter Sandstones*)	611	0	**1784**	**0**
PERMIAN				
(*Upper Magnesian Limestone*)	61	0	1845	0
(*Middle Marls*): Sandstone, marl	70	0	1915	0
(*Lower Magnesian Limestone*)	246	0	2161	0
Grey shales (Marl Slates)	172	0	2333	0
Breccia	3	0	**2336**	**0**
COAL MEASURES (*Middle*)				
Shales, fireclays, sandstones, marls	338	0	2674	0
Blue shale and fireclay	27	0	2701	0
Coal and black shale (TOP HARD) ..	9	0	**2710**	**0**
Clunch, sandstone and shale	164	6	2874	6
Coal (cannel)	1	6	**2876**	**0**
Clunch, etc.	23	6	2899	6
Coal and clunch	8	0	**2907**	**6**
Clunch, shale, sandstone and ironstone ..	32	0	2939	6
Coal	1	3	**2940**	**9**
Clunch, bind and ironstone	14	7	2955	4
Coal (cannel) and shale	0	6	**2955**	**10**
Clunch, bind and ironstone	21	8	2977	6
Coal (cannel)	0	7	**2978**	**1**
Shale, fireclay and sandstone	19	7	2997	8
Coal	1	1	**2998**	**9**
Sandstone, shale and fireclay	80	3	3079	0
Coal 10-in., fireclay and **Coal** 7-in.	6	10	**3085**	**10**
Blue bind, *Lingula* at 3128 ft.	48	3	3134	1
Coal with parting	5	11	**3140**	**0**
Clunch, sandstone, shale with ironstone ..	121	9	3261	9
Coal	1	6	**3263**	**3**
Fireclay, sandstone and shale	52	2	3315	5
Coal and clunch	2	5	**3317**	**10**
Fireclay and shale with ironstone	36	3	3354	1
Coal	1	8	**3355**	**9**
Fireclay, sandstone and shale	248	3	3604	0

The bore was put down by the Trefor Co. for the Lincolnshire Boring Syndicate. The diameter of the hole was 18 in. at the top, 7 in. at the base of the Permian and 3¾ in. at the bottom. The percussive method of drilling was used to a depth of 1,200 ft., the chilled shot process to 2,340 ft. and the diamond crown for the remainder.

The base of the Permian is well defined by the breccia at a depth

[1] See Ford, J., 'The Lincolnshire Coalfield, etc.' *Trans. Inst. Min. Eng.*, vol. lxxii, pt. 5, 1927, pp. 238–254.

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of 2,336 ft. The overlying 'Marl Slates' have yielded the Permian plant *Ullmania bronni*.

An interesting feature of the boring is the depth to which the Coal Measures sediments are stained red and purple below the base of the Permian. In most cases the reddening of the measures only extends for a depth of 20 ft. or so. Here, however, it occurs for a distance of over 330 ft. down into the Coal Measures, and in some cases individual beds contain sufficient ferruginous matter to be classed as impure iron ores. The staining has affected both the shales and the sandstones; and some of the coarse grits are now quite unlike normal Coal Measures in appearance. When it is considered that the top 200 ft. of these beds are mainly of a marly nature, and so more or less impervious, the great depth to which the staining has permeated is remarkable, and suggests that the bore is situated near a fault or other line of weakness.

The cores are preserved in a shed, and permission has been given for their systematic breaking-up as soon as certain business negotiations are concluded. Up to the present no marine shells have been noted in the 367 ft. of strata occurring between the base of the Permian and the Top Hard Coal, but a length of the cores is covered up and has not yet been examined.

The identification of the Top Hard rests on the presence of cannel in the roof as at Sutton, and of the occurrence of good 'hards' in the materials shown us by Mr. Ford as having come from this horizon. A bed of blue shale containing *Lingula*, and associated with shales yielding *Carbonicola* occurs at a depth of 3,128 ft. It is taken as representing the marine bed which at Ollerton and Wellow respectively occurs 375 ft. and 350 ft. below the Top Hard Coal, as compared with 420 ft. here at Doddington. At Sutton the distance between the same horizons is only 226 ft., but the apparent thinning may be due to the Sutton boring having passed through a fault. On the other hand it is just possible that the coal at 2,703 ft. is not the Top Hard, but the High Hazel of Thorne. The seam at 2,899 ft. would then be regarded as the Top Hard, and its distance above the *Lingula* bed is about 223 ft. which compares very well with the 226 ft. at Sutton. With this reading there is no need for supposing the presence of a fault at Sutton, and a distinct thinning of the beds between the Top Hard Coal and the marine bed is shown to occur to the north and east of Ollerton.

No workable seams of coal were encountered at the positions of the Deep Soft and Deep Hard Coals. This is remarkable; since both Ollerton and Wellow borings proved quite good seams at these horizons.

With the aid of the information supplied by the Sutton bore an attempt is made at a reading of the section proved at Crosby. It has already been pointed out that three beds with marine shells or *Lingula*, the Mansfield Marine bed being the uppermost, occur within a belt of about 80 ft. of strata at Sutton. At Crosby three beds

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with similar characteristics were noted within a thickness of about 100 ft. of sediment.[1]

In each case the general succession above this belt of marine beds is the same. It is suggested, therefore, that the bed at 3,240 ft. at Crosby is the Mansfield Marine Bed, that the marine bed at 3,322 ft. is the roof of the Abdy Coal (this latter suggestion was originally made by Professor Kendall and Culpin), and that the Barnsley Coal occurs in this area at a depth of between 3,700 ft. and 3,750 ft. or less than 100 ft. below the point at which the bore was stopped. If this reading is correct it implies a diminution in the rate of thinning of the measures between the Mansfield Marine Bed and the Barnsley Coal to the east of Thorne.

It will also be seen that the Barnsley Coal at Crosby is taken as lying about 1,000 ft. deeper than at Thorne Colliery. The distance between the two places is 10 miles. This gives a rate of fall of about 1 in 53, which is approximately the amount proved in the Thorne workings in the direction of Crosby.

When this reading of the Crosby section is considered in conjunction with the evidence of the Doddington bore it would appear that there is no proof of a rise of the Coal Measures to the east in this part of the Concealed Coalfield. Also with the possibility of the seam at 2,703 ft. at Doddington being the High Hazel of Thorne and Hatfield it is possible that that valuable seam may have quite a considerable extent in this part of the coalfield. Further evidence for this suggestion is afforded by the recording of a 2 ft. 6 in. seam of coal in what may be regarded as the same position in the Crosby bore.

[1] See 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 2nd Edition, 1926, p. 113.

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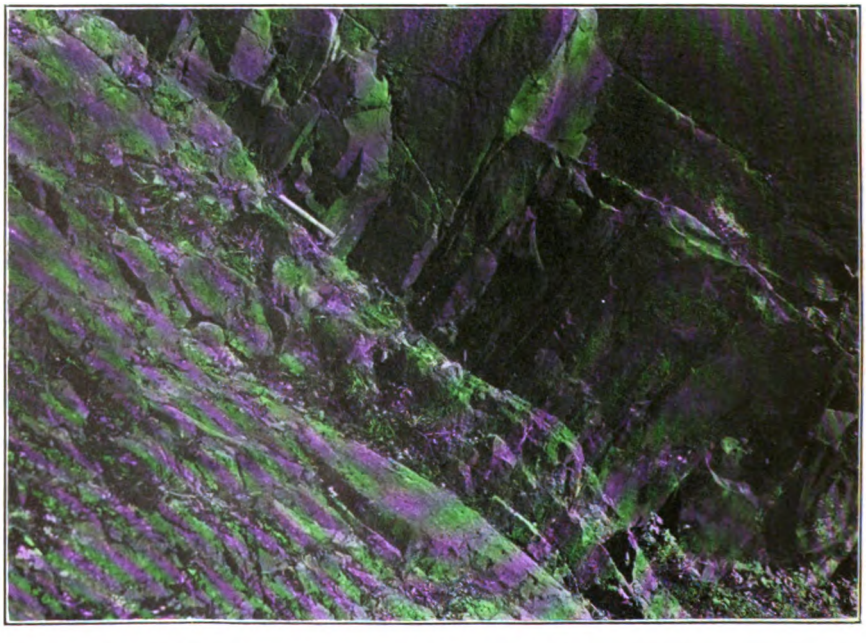
(A). *The Ochil Hills, from Stirling, showing the* ***fault-feature*** *;* ***Abbey Craig*** *sill escarpment in middle distance.*



(B). *Gloom Hill Quarry, Dollar, showing dolerite* ***intrusion against north*** *face of fault, with hade to the* ***south.***

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APPENDIX VIII

The Ochil Fault and its Dolerite Intrusion

By D. Haldane, B.Sc.

Plate 1. Text-figures 1, 2.

Introduction.—The Ochil Fault, running along the south foot of the Ochil Hills, is a great east-and-west fracture which at places may be a single line, but elsewhere appears to be a belt or zone of some breadth. Bringing the Productive Coal Measures against lavas of Lower Old Red Sandstone age, it forms the northern boundary of the Clackmannan coalfield, and has a downthrow, at a minimum estimate, of 5,500 ft. to the south.[1]

This great dislocation is known to extend westwards beneath the alluvial or 'carse' lands of the Forth west of Stirling,[2] and along the foot of the Gargunnock Hills, while to the east it skirts the northern slopes of the Cleish Hills, passes through Blairadam into the highly faulted coalfield of Benarty and Lochore in central Fife—a total distance of 35 miles—and can be traced some twenty miles further to the sea. These continuations have considerably smaller throws than the central Clackmannanshire portion, the Ochil Fault proper.

The south face of the Ochil Hills is a notable example of a fault-feature (Pl. I, A), the bold craggy escarpments of the lavas and agglomerates, which rise steeply to an average elevation of 1,500 ft. above the carse of the River Devon, being in strong contrast both to the low-lying smoothly undulating drift-covered Carboniferous country on the south, and to the more gradually sloping heath-covered northern side of the range. The continuity of the escarpments is interrupted by a series of metalliferous faults, with N.N.W. trend and downthrow mostly to west[3] (these are probably pre-Carboniferous since little or no trace of faults with this direction has been found on the south side of the fault), and by numerous stream-courses and gullies, the exposures in which enable the line of the fault to be mapped with considerable accuracy to the east of Alva.

Two branches of considerable size diverge from the south side of the fault, both with southerly downthrow and with a general E.S.E. direction which corresponds to the main system of faulting

[1] The actual displacement is undoubtedly greater, and was estimated by Sir A. Geikie as hardly less than 10,000 ft. 'Geology of Central and Western Fife and Kinross-shire' (*Mem. Geol. Surv.*), 1900, p. 175.

[2] 'Summary of Progress' for 1921 (*Mem. Geol. Surv.*), 1922, p. 82.

[3] *Ibid*, p. 82; see also 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xvii (The Lead, Zinc, Copper and Nickel Ores of Scotland), 1921, p. 142.

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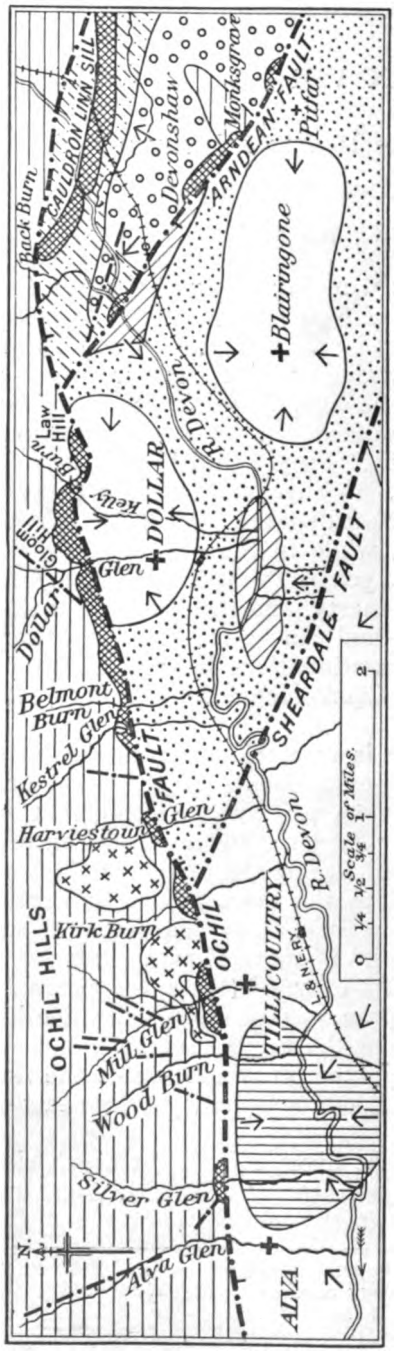

FIG. 1.—*Sketch Map showing the Ochil Fault and Dolerite Intrusion.*

in the West Fife coalfield. The Arndean Fault is much the more important, throwing the Upper Limestone Group of the Carboniferous Limestone Series against Upper Old Red Sandstones, and at one place (Monksgrave) bringing Millstone Grit opposite an inlier of Lower Old Red lavas. This branch continues for over two miles S.E. of Pitfar, after which it perhaps loses its individuality in the disturbed volcanic region of the Saline Hills.

Two features of the Ochil Fault are of particular interest: the direction of its hade, which has been disputed, and the quartz-dolerite intrusion along the fault-zone. These are dealt with in the following paragraphs in the light of new information collected during the recent revision of the adjoining coalfield.

Summary of local details.—In the western continuation of the Ochil Fault, no intrusion is found at Kippen, where Upper and Lower Old Red Sandstones are brought against each

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other, nor is there any exposure in the R. Forth near Craigforth, although rock is probably near the surface, since Lower Old Red mudstones and sandstones and Calciferous Sandstone lavas, on opposite sides of the fault-line, peer through the carse deposits only a few hundred yards apart. The fault is obscured by drift to the N.E. of Stirling and by alluvium as far as Alva (reported by Dr. H. H. Read), but from this point eastwards it can be observed in most of the following sections (arranged from west to east) :—

Ochil Fault

1. Alva Glen.
2. Silver Glen.
3. Wood Burn.
4. Castle Craig Quarry.
5. Mill Glen.
6. Kirk Burn.
7. Harviestoun Glen.
8. Kestrel Glen.
9. Belmont Burn.
10. Dollar Glen.
11. Gloom Hill.
12. Kelly Burn.
13 Law Hill.
14. Back Burn.

Arndean Fault

15. R. Devon at Arndean.
16. Streamlet ⅜ m. E.S.E. of do.
17. Devonshaw Quarry.
18. Monksgrave.
19. 750 yds. E. of Pitfar House.

The phenomena observed at these exposures may be summarised as follows :—

(*a*) Fault-intrusion definitely absent in 1 ; probably absent, or at least thin, in 3, 14, 16, 18 ; present in 2 (width about 50 yds.), 4, 5 (70 yds.), 6 (60 yds. tapering to east), 7 (25 yds., very decomposed), 8 (about 120 yds. in all), 9 (60 yds.), 10 (about 160 yds.), 11, 12 (50 yds. or more), 13, 15 (thin and decomposed), 17 (200 yds. tapering to south-east), 19 (an isolated knob, very vesicular). In addition, it appears probable, though definite proof on this point is lacking, that the intrusion is thin or absent, on the hill side between 2 and 3 and 4, 5 and 6, 6 and 7, and 7 and 8 ; it is present in fair thickness between 9 and 10.

(*b*) The intrusion shows a chilled margin against the rocks on its north side at localities 2, 4, 5, 6, 7, 9, 11, 13, and 17, and against those on its south side at 5, 8, and 9. The transition from chilled edge inwards through fine-grained to coarse dolerite is well seen at 4, 5, 6, 8, 9, 11 and 17.

(*c*) Definite signs of subsidiary fracture are frequently found in the strata adjoining the main and the Arndean faults ; north of the fault at 2, 13 and 15, and south of it (the faults being generally parallel to the Ochil Fault) at 5, 6, 7, 8, 12 and 15. At localities 2, 6, 7, 13, and 19, this minor faulting affects the intrusion itself, and must be of later date.

(*d*) The northern face of the fault has been bared at three places by quarrying-away of the intrusion. The hade is there found to be southerly, and inclined 72° to the horizontal at 4, 63° at 11 (Pl. I, B), and 70° at 17.

At Castle Craig Quarry (4) the Old Red ash on the north side of the fault is hornfelsed, evidently by a hypersthene-diorite intrusion which is strongly developed hereabouts, and not by the

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dolerite. The 'baking' effects of the latter are less intense, and may be observed at Devonshaw Quarry (17), and at Kestrel Glen (8), where a mass of Carboniferous sandstone and shale some 75 yards long has been engulfed and hardened by the intrusion, and now lies against the northern face of the fault. The sandstones south of the dolerite here are locally black, a circumstance perhaps due to 'burning' of an original petroleum content.

To the east of locality No. 14, the Ochil fault-line is obscured for about five miles as far as Hardiston, where it is seen in two stream sections without a trace of dolerite, and Mr. J. K. Allan records none in its further eastward extensions. The quartz-dolerites at Cauldron Linn and at Cult Hill (1 mile E. of Pitfar) are sills intruded into Calciferous Sandstone strata, and have no visible connection with the fault-intrusion.

The trend of the fault-line averages E. 15° N. in the area under consideration, but between localities 11 and 13 appears to deviate to E. 20° S. As in the case of the extraordinary bend in the great Campsie Fault north-west of Kilsyth, we cannot say for certain whether the swing is an appearance due to subsequent faulting of the main by a cross fracture; the evidence is, however, against this explanation.

The Intrusion: Petrography.—The intrusion along the Ochil Fault is a tolerably uniform quartz-dolerite similar to those repeatedly described from other parts of Scotland. The coarse varieties are seen in thin slice to consist of a subophitic association of basic plagioclase, pale greenish augite and iron ore; the acid mesostasis is represented by abundant well-developed micropegmatitic quartz and alkali felspar. Acid segregation veins are widespread. In slices from certain localities hypersthene is present. The marginal varieties of the intrusion show tholeiitic types, whilst others, by the acicular development of their components, approach the craignurite of Mull.

The Intrusion: Field relations.—The above record of exposures shows that the quartz-dolerite is definitely intrusive in the fault-zone, showing chilled edges against one or both fault faces at most localities. It cannot, therefore, as has been suggested, be a sill of earlier date, upturned by the drag of the fault. Faulting later than the intrusion must have been relatively insignificant, or the indications of subsidiary fracture along the line could scarcely fail to be more intense than appears to be the case. Although, then, movement is still taking place along or near the Ochil Fault (see next section) by far the greater amount of the displacement must have been produced prior to or along with the intrusion of the dolerite.

There seems little doubt that the various exposures may be safely regarded as parts of one intrusive unit, connected with that great suite of quartz-dolerite sills and east-and-west dykes, so abundant in the Central and Fifeshire coalfields, which is now

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generally considered to be of Permo-Carboniferous age.[1] The sills of this suite are developed mainly in the lower part of the Carboniferous, less frequently in the Millstone Grit and Coal Measures, and almost invariably avoid the Old Red Sandstone. In the country immediately south of the Ochil Fault and its continuations, these sills are not, except in central Fife, found higher than the Carboniferous Limestone, but occur in the middle and lower groups of that Series (as at Abbey Craig and Stirling, and in bores eastwards to West Fife) and in the upper group (bore 3½ miles S. of Dollar): they also occur in the Calciferous Sandstones (5 miles S.S.W. of Stirling, and Cauldron Linn and Cult Hill already referred to).

It is difficult to avoid the impression that the Ochil fault-intrusion represents a part of the magma of these petrographically very similar sills, seen here in the stage of abrupt transgression from one level to another. Such 'jumping' has been proved at several places in the Central Coalfield, and is probably not uncommon elsewhere. Planes of jump may be (1) long 'primary' east-and-west dykes, which evidently rise from considerable depth as their course is unaffected by the offshoot sills, or (2) 'secondary' dykes, vertical links between portions of a sill at two different levels—dyke-like when the jump is sufficiently abrupt, but without direct connection with the deeper-seated parts of the magmas. Jump may also occur along fault-planes; up to the present this has perhaps been demonstrated only for certain east-and-west faults where their course is followed by a 'primary' dyke (such dykes may follow deviations from the normal trend of the fault, when not too sudden or prolonged), but there seems no valid reason why 'secondary' dykes should not do the same. There being none of the 'primary' dykes in the neighbourhood, and, as has been already noted, no intrusion along the fault west of the Stirling sills, the Ochil fault-intrusion may, on this view, be a 'secondary' dyke, connecting the quartz-dolerite sills of the coalfield to others which may have once extended over the site of the Ochil Hills, probably at a low Carboniferous horizon, but are now represented only by their denuded relics in the east—Benarty and the Lomond Hills of Fife.

The discontinuity of the fault-intrusion is interesting but not unlooked for. Even ordinary dykes, whose width, as might be expected, is not usually liable to rapid variation within short distances, have repeatedly been proved to stop suddenly in places and fail to reach the surface[2]; while it is well known that the continuity shown on maps is rarely other than diagrammatic. But in the case of an intrusion along a fracture or fault-zone, which, not being absolutely plane when initiated, cannot have had parallel sides after

[1] 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), 2nd edit., 1925, pp. 149–152.

[2] Teall, J. J. H., 'Petrological Notes on Some North of England Dykes,' *Quart. Journ. Geol. Soc.*, vol. xl, 1884, pp. 210–211. Barrow, G., 'The Geology of North Cleveland' (*Mem. Geol. Surv.*), 1888, p. 61. Geikie, A., 'Ancient Volcanoes of Great Britain,' vol. ii, 1897, pp. 142, 147–150.

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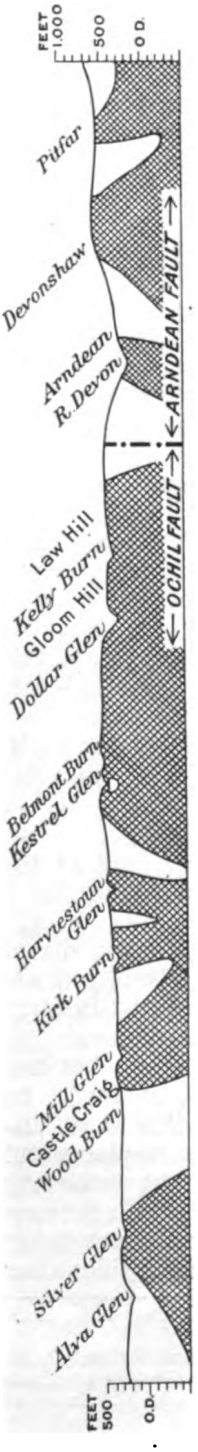

FIG. 2.—*Diagrammatic Section showing Conjectural Profile underground of the Dolerite Intrusion.*

movement ceased, discontinuity is still more likely. It will be equally likely at all levels, and as it is not reasonable to suppose that the variations of the intrusion can have been influenced by the present surface (an accident of subsequent prolonged erosion), the conjectural, deeper, parts of the profile (Fig. 2) are drawn discontinuous, like the observed portions, the section thus appearing as a part of a reticulate whole.

The Hade of the Ochil Fault.—It has already been mentioned that the hade of the northern face of the fault is clearly seen at three places to be inclined to the south. Now the Hillsfoot villages (a name sometimes given to Alva, Menstrie, etc.) are well known for the frequency of their earthquakes, over 200 shocks being known since the year 1736; from a study of the records Dr. Davison[1] has concluded that the shocks originate, often at comparatively shallow depths, in movement along a fault line which, like the Ochil Fault, passes close to the Hillsfoot villages with an average direction of N.77°E., but hades towards the north. "The seismic evidence," he says in a paragraph devoted to the origin of the Menstrie earthquakes,[2] "gives the following elements for the originating fault: (i) The direction of the longer axis of the isoseismal lines . . . averages N.77°E. (ii) The direction of the hade of the fault is indicated by the relative positions of the isoseismal lines of the earthquakes of 1905, Sept. 21, and 1912, May 3. As these lines are farther apart on the north side than on the south, the fault should hade to the north. (iii) The fault-line should therefore pass through a point a short distance to the south of the epicentres of these earthquakes. . . .

"Again, that the fault should hade to the north is shown by the distribution of the known epicentres (Fig. 18), which all lie on the north of the indicated fault-line and are grouped in a band which is roughly parallel to it.

"On the maps of the earthquakes (Figs. 12-17) . . . it satisfies two of the conditions required by the seismic evidence. On the other hand, as

[1] Davison, C., 'A History of British Earthquakes,' 1924, pp. 123–151.
[2] *Ibid*, pp. 149–151.

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Dr. J. Horne, F.R.S., has kindly informed me, the fault . . . is exposed in two or three places . . . the hade being to the south. This is, I believe, the only case in which the seismic evidence and the geological evidence seem to conflict. It may be that, owing to the presence of the Ochil Hills, the isoseismal lines are distorted to an unusual extent towards the north, but the seismic evidence in favour of a northerly hade is so strong that I do not think that the discrepancy can be thus explained."

Old colliery plans show that, as usual, northward working was stopped on reaching the 'troubled zone,' but though this lies south of the surface position of the fault it yields no proof of a southerly hade, since the zone of disturbance may be of considerable width.

A northerly hade would make the Ochil Fault a reversed fault, such as is rare in the absence of lateral pressure; it would be natural if the Ochil Hills had been thrust over the coalfield at their foot, but of this there is no evidence. The chief faults in the coalfield, three or four in number and each of 500 to 600 feet displacement, run approximately east and west for not less than 9 or 10 miles, suggesting some relationship to the Ochil Fault. They have been encountered here and there in workings, and proved to be normal faults, with hade and downthrow always to the south, like the Sheardale and Arndean faults. Faults with downthrow to the north are almost unknown. Were this coalfield being overridden from the north, it might be expected to show subsidences towards the north along normal faults, or, if at all sharing the overriding movements, to contain reversed faults hading to the north; the stepped series of normal faults, hading south, which is actually found scarcely supports the conception of a thrust from the north, and suggests rather that the Ochil Fault is but one more step in the series, and the largest.

Nor is it reasonable to suppose that in all three exposures the fault zone has been widened upwards by the intrusion with such regularity as to present a natural-seeming hade which is the direct opposite of the true hade. In any case the evidence is against such widening; in more than one instance portions of the downthrown sediments are still to be found against the northern fault face with dolerite close above or to south of them (localities 4 and 8).

In fact, the geological evidence of hade is as strong as it can be, and if the fullest allowance for the very different nature and topography of the rocks on either side of the fault should leave the seismic evidence unaltered, the best way out of the dilemma appears to be along the following lines. Either the Ochil Fault is normal near the surface of the ground, and steepening its hade passes into a reversed fault at no great depth; or the fracture indicated by the earthquakes is not the Ochil Fault, but another—possibly one hitherto undetected because it is too small, or because it meets the plane of the Ochil Fault before reaching the surface; or lastly, simultaneous movements along the Ochil Fault and the series of N.N.W. presumably pre-Carboniferous faults in the Old Red lavas north of the Menstrie—Alva segment may combine to produce a resultant seismic effect like that which is actually observed.

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APPENDIX IX

Fossils from the Ironsands on Netley Heath (Surrey)

By C. P. Chatwin, M.Sc.

Fragmentary remains of fossils have occasionally been found in the ferruginous sands just above the 600 ft. contour on the North Downs at Netley Heath, midway between Guildford and Dorking, about 2 miles south of West Horsley. The first record was made by Mr. W. P. D. Stebbing[1] and later finds by Mr. W. Wright were recorded by Mr. G. M. Davies,[2] but the fossils were so poorly preserved that only generic determination was possible. On account of the lithological character and mode of occurrence of these deposits it has generally been thought that they would prove to be of the same age as the Lenham Beds of Kent.

During the course of the resurvey of the area, special search was made by Mr. S. W. Hester, with the result that 89 rock-specimens, containing 111 separate fossils, were collected. These fossils occur either as moulds, casts, or comminuted fragments, and in almost every case the use of modelling-wax or gutta-percha is necessary for adequate interpretation. In a few instances the fossils are preserved in a ferruginous fine-grained micaceous sandstone. Other specimens are found in a conglomerate of rounded and polished quartz grains of varying size, cemented by limonite and sometimes including tiny chips of flint and lumps of greensand chert. Occasionally the matrix is accompanied by veins and layers of iron-pan and the fossils are thoroughly comminuted. Except for the fine-grained sandstone (which is similar at both localities) the Netley Heath fossiliferous material differs from the Lenham sandstone in being for the most part conglomeratic, the moulds or casts of the Lenham fossils being nearly always complete.

From among the material now available from Netley Heath at least one diagnostic species can be satisfactorily determined, namely *Corbulomya complanata* Auctorum.[3] This form is represented by 31 examples, nearly all casts of right valves. Not only can the external features of the shell be reproduced by modelling-wax, but the details of the dentition can be ascertained by the same means. It should be noted that the external features of the Netley Heath examples of this shell differ slightly from J. Sowerby's type[4] and

[1] 'Excursion to Netley Heath . . .', *Proc. Geol. Assoc.*, vol. xvi, 1900, p. 525.

[2] 'Excursion to Netley Heath . . .', *Proc. Geol. Assoc.*, vol. xxviii, 1917, p. 50.

[3] But not of those in the synonymy of *Corbulomya turonica* Cossmann. G. F. Dollfus and P. Dautzenberg, 'Conchyliologie du Miocène moyen du Bassin de la Loire,' Pt. 1, *Mem. Soc. géol. France, Paléontologie*, vol. x, 1902, fasc. 2–3, p. 86.

[4] *Corbula complanata*, 'Mineral Conchology,' vol. iv, 1822, pl. 362, figs. 7 and 8, p. 86.

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from typical examples from the Red Crag of East Anglia.[1] These forms have a slightly convex ventral margin and taper gently anteriorly, while the margin of the truncated portion slopes perceptibly backwards. The Netley Heath specimens are more subquadrate. They can be matched exactly, however, with specimens recognized as this species from the Scaldisian of Calloo, near Antwerp, and from the Scaldisian or Poederlian of the Oss Boring, Holland (32–52 metres from the surface). This species is restricted in range to these two horizons in the Pliocene series of Belgium and Holland and to the Newbournian and Waltonian divisions of the Red Crag in England.[2] It is the commonest and most definite member of the Netley Heath assemblage, but the following forms can be recognized with a fair degree of certainty :

Cerastoderma edule (Linn.), var. *edulinum* (J. Sowerby).

Impression of ribs on ventral margin, with the characteristic imbrication of that variety.

Mytilus edulis Linn.

Natural cast of right valve, with eroded umbo.

Pholas sp.

Two fragments showing impressions of external imbricating ridges, from under the reflected antero-dorsal portion of the shell.

Ostrea princeps J. Sowerby.

Two fragments which match exactly the lamellated costae of this species.

Purpura lapillus (Linn.), var. aff. *P. tetragona* (J. Sowerby).

This form is represented by an external mould of three upper whorls. The whorls are rapidly expanding, inflated, and bluntly carinated. The dominant ornamentation consists of six stout rounded spiral ridges. The subordinate transverse ornament consists of traces of incipient varices, seen on a wax impression as blunt swellings, with occasional ridges between the spirals but not crossing them. Harmer showed *Purpura lapillus* to be an extremely variable species, some forms being connected with *P. tetragona* [3]

Balanus sp.

Isolated valves—carino-latus and basis.

Other forms can be referred (with some little doubt on account of the imperfect state of preservation) to the following :—

Turritella cf. *tricarinata* (Brocchi).

Three specimens exhibit whorls which show traces of ornament. Five other specimens probably belong to the same form : they show no ornament but retain the whorl-outline with the sharp anterior truncation. A definite determination might be made but for the fact that the three major spirals are equal in strength : in *T. tricarinata* the middle spiral is stronger than the others.

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[1] Wood, S. V., ' Monograph of the Crag Mollusca,' part 2 (*Palæontographical Soc.*), 1856, p. 275, pl. xxx, figs. 2 (as *Corbula complanata*).

[2] Tesch, P., ' Beiträge zur Kenntnis der marinen Mollusken im West-Europäischen Pliocänbecken,' *Mededeel. van de Rijksopsporing van Delfstoffen*, no. 4, 1912, pp. 11 and 58.

[3] Harmer, F. W., ' The Pliocene Mollusca of Great Britain,' pt. 1 (*Palæontographical Soc.*), 1914, p. 117.

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Cerastoderma edule (Linn.), var.

Impression of ribs with growth-pauses.

Ostrea sp.

Internal cast of right valve of a very short form: might be compared with a form of *O. edulis* Linn.

Astarte sulcata Da Costa.

Impression of ornament showing fine ribs between the concentric ridges.

Barnea cylindrica (J. Sowerby).

A fragment from the anterior part of a small form of this species.

Laevicardium norvegicum (Spengler).

Two impressions of ornament bear comparison with decorticated examples of this species.

Further determinations include:

Mactra spp.

Impression of the interior of one small left valve showing dentition; and of the dentition of a larger right valve.

Pectunculus sp.

Natural cast of a very small valve, showing dentition.

Cyprina sp.

Two indeterminable natural casts.

The assemblage includes also casts of two lamellibranchs which cannot be referred to any genus, and a part of the claw of a small crab.

As previously mentioned, the mode of occurrence of the Netley Heath sands has suggested comparison with similar beds at Lenham. The fauna of the Lenham Beds, however, is well known, and the principal authorities (Reid, Harmer, and R. B. Newton) were agreed as to its essential features.[1] Comparison between the assemblages of fossils in the sands at Netley Heath and at Lenham has hitherto been impossible by reason of the paucity and the fragmentary nature of the finds from the former locality. The specimens now collected, however, should be sufficient in number to be regarded as a typical assemblage; and this assemblage is clearly not that of the Lenham Beds. Although such recent species as *Trivia europaea* (Montagu), *Aporrhais pes-pelicani* (Linn.), *Æquipecten opercularis* (Linn.), and *Dentilucina borealis* (Linn.) have been found at Lenham, a typical sample of the Lenham fauna should include *Arca* (*Anadara*) *diluvii* (Lamarck), *Papillicardium papillosum* (Poli), and *Ringiculella*

[1] Reid, C., 'The Pliocene Deposits of Britain' (*Mem. Geol. Surv.*), 1890, pp. 42–58; F. W. Harmer, 'The Pliocene Deposits of the East of England: the Lenham Beds and the Coralline Crag,' *Quart. Journ. Geol. Soc.*, vol. liv, 1898, p. 308; also 'The Pliocene Mollusca of Great Britain,' vol. ii, pt. 1 (*Palæontographical Soc.*), 1920, p. 487; R. B. Newton, 'The Conchological Features of the Lenham Sandstones of Kent and their Stratigraphical Importance,' *Journ. of Conchology*, vol. xv, 1916, pp. 56–149, pls. 1–4.

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lenhamensis R. B. Newton. These are very common at Lenham, where, in association with *Ficula*, *Phorus*, *Triton*, and *Avicula*, and southern extinct species of *Pleurotoma* and *Terebra*, they impart a facies to the fauna indicating, according to R. B. Newton, a southern or Mediterranean origin. On account of the strong percentage of extinct (particularly Miocene) forms Newton correlated the Lenham Beds with the Upper Miocene.[1]

The characteristic elements of the Lenham fauna, then, are not represented among the specimens at present collected from Netley Heath. On the other hand, the commonest species at Netley Heath (and its comparative frequency there must be duly assessed) is *Corbulomya complanata*, a shell typical of the Scaldisian and Poederlian horizons. If we regard the common occurrence of this species as indicative of the Newbournian and Waltonian divisions of the Red Crag in Harmer's Upper Pliocene[2] (the Middle Pliocene and lower part of the Upper Pliocene of Tesch[3]), we can consider this assumption as strengthened by the presence, in the same assemblage, of *Purpura lapillus*, var. and *Cerastoderma edule*, var. From the material at present available we may, in fact, conclude that the assemblage is different from that found at Lenham and that it is not older than Harmer's Upper Pliocene. It must be borne in mind, however, that the age of the assemblage is not necessarily the same as that of the deposit in which it occurs. The comminuted condition of the shells and the conglomeratic nature of the matrix in which they are enclosed are not discordant with the possibility of their having been transported from a distant source.

[1] *Op. cit.*; and *Geol. Mag.*, 1917, pp. 259–269, 320–326.
[2] *Op. cit.*
[3] *Op. cit.*

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APPENDIX X

The Superficial Deposits in the Clyde Valley at Bonnington, 1½ miles S. of Lanark

By G. Ross, B.Sc.

Text-figure 1.

These notes are based on the borings and excavations made in connection with the tunnel now in course of completion at Bonnington for the Clyde Valley Hydro-electric Power Scheme. Certain preliminary observations on the materials exposed at the north or lower end of the tunnel were given in the 'Summary of Progress' for 1925[1]; but the opening up of new sections this year has added considerably to our knowledge of the superficial deposits in this part of the Clyde Valley. Sir Wm. Arrol & Co., Ltd., the Contractors, kindly gave every facility for inspecting the excavations, and Fig. 1 has been largely compiled from data and sections supplied by them.

The new sections provided fine exposures of deposits previously proved only in borings; and the details of Shaft No. 3 (Fig. 1), numbered from below upwards, are as follows:—

		Ft.
(v)	Fine sand, clay, and gravel resting on horizontally bedded sand; top layers not well seen ... ... about	8
(iv)	Boulder-bed of angular boulders, up to 3½ ft. in diameter, chiefly of flaggy red and purple sandstone of Lower Old Red type; clayey silt below ... ... about	3
(iii)	(*b*) Fine horizontally bedded sand with a few layers of coarser material and many laminae and fragments of coal in lower layers ... ... about	27
	(*a*) Fine laminated sand and sandy clay; coal fragments less abundant than in (*b*)... ... ... about	10
(ii)	Boulder Clay: abundant striated boulders up to 2 ft. in diameter embedded in a purplish sandy clay ... about	5

A rough analysis of the boulders present in (ii) shows that the larger ones consist of flaggy red and purple sandstones of Lower Old Red type, while the smaller ones include, in the order of their relative abundance, Carboniferous limestone, Old Red andesitic lava, felsite and porphyrite, coal, greywackes, chert, cornstone, and clayband ironstone.

The second section, an opencast working along the line B–C of Fig. 1, carried to a depth of about 45 ft., gave a very similar succession, but here the boulder-bed (iv) is seen to be thinning out in a southerly direction. The fragments of coal in (iii) are also less numerous in this section.

From the evidence of Bores 7, 8, and 9, the line of the tunnel appears to pass over a pre-glacial channel whose lower part is filled

[1] (*Mem. Geol. Surv.*), 1926, p. 115.

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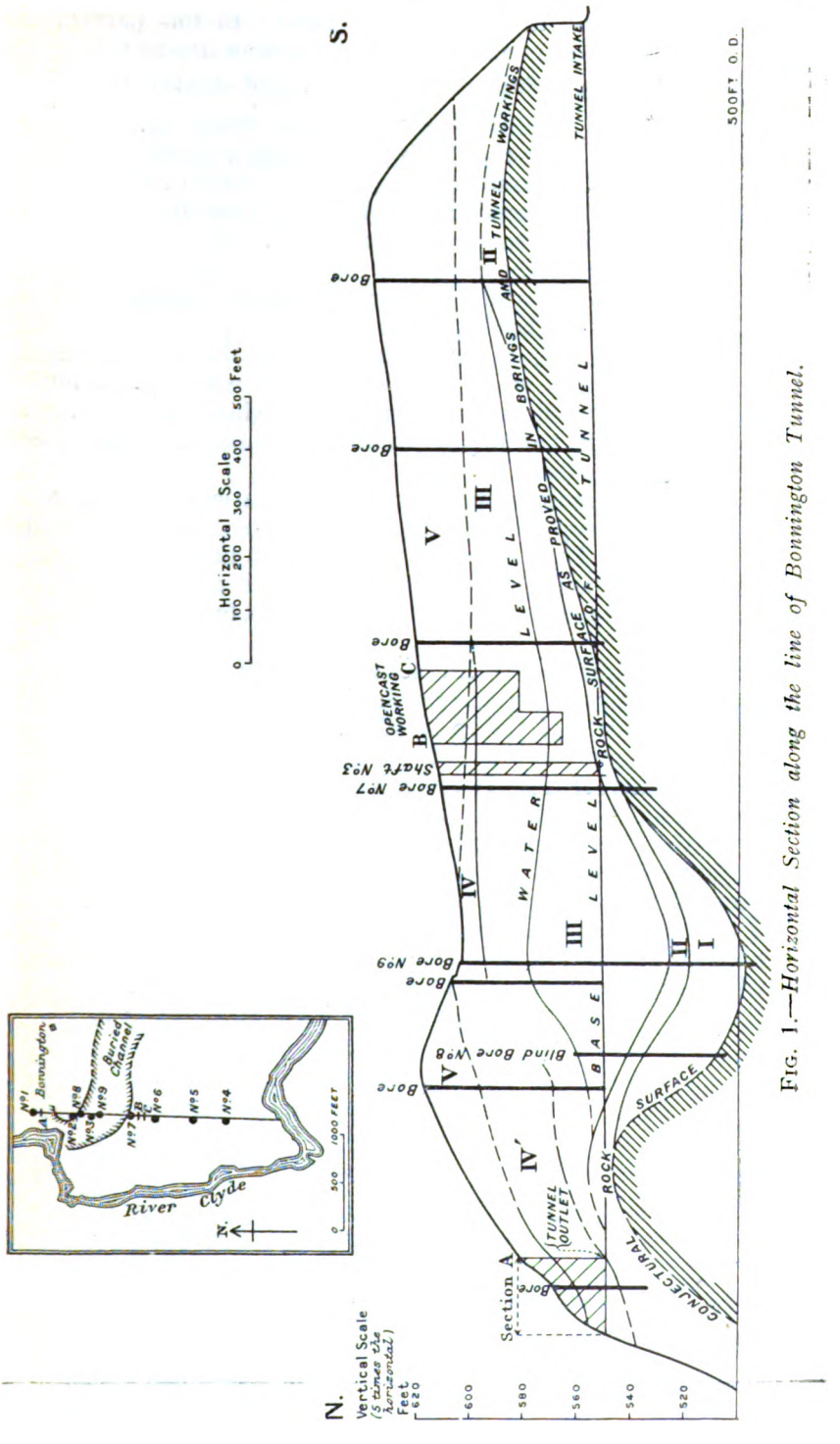

FIG. 1.—*Horizontal Section along the line of Bonnington Tunnel.*

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by muddy sands and clays (? alluvial silts). In this part of the section therefore the sequence is continued downwards as follows :—

(i) Clayey silts, underlying boulder-clay in buried channel (Fig. 1).

As regards the conditions under which these deposits were accumulated, the boulder-clay of (ii), containing a mixed assemblage of rocks, represents apparently the ground-moraine of the Douglas Valley Glacier which entered the Clyde valley from the south-west.

The Douglas valley traverses mainly Carboniferous rocks, from which the majority of the boulders may well have been derived, and its eastern edge is formed in part by andesitic lavas, which are also represented in the boulder-clay.

The deposits of (iii) are due probably to the melting of the Douglas Valley Glacier while the Clyde valley was blocked by ice at some point farther down its course ; the white sands and silty clays with coaly laminae may be closely matched with the present alluvial sands and silts of the Douglas Water.

Group (iv) is more difficult of interpretation. The angular boulders of this group were perhaps dropped by ice-rafts stranded in shallow water. They are quite unworn and have evidently not been carried far ; and they can be well matched with the Lower Old Red Sandstone rocks seen in the present Clyde gorge close at hand.

This group is quite local and dies out entirely to the south, while it is apparently replaced to the north by the steeply current-bedded gravels and boulders of Group iv′ (Fig. 1).

The gravels and boulders of Group (iv′) are similar to those exposed in Section A (Fig. 1) which have been ascribed to torrential deposition from the melting of Southern Upland ice[1].

The overlying horizontally bedded sands and gravels of Group (v), seen in that section and proved in borings elsewhere along the line of the tunnel, appear to form part of the denuded remnant of a wide-spread terrace, reaching in many places in the neighbourhood to the 700-ft. contour, and deposited on the surface of the terrace of Group (iii), which reached nearly to the 600-ft. contour (Fig. 1).

[1] *Op. cit.*, p. 115.

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APPENDIX XI

On a new species of Sutcliffia

By R. Crookall, Ph.D.

Plate I.

The occurrence of petrified plant-remains in the Pennant Rock of the Bristol and Somerset and the South Wales Coalfields has been known for a considerable time, but no work describing these fossils has yet been published.

In the Bristol area D. G. Lillie[1] has recorded a small amount of material showing structure which was found in a conglomerate at the base of the Pennant Rock at Staplehill, and, among other fossils, referred to " a specimen of a well-preserved *Myeloxylon*, the petiole of a Medullosa." This type of petiole was originally included in the genus *Myelopteris* Renault (= *Myeloxylon* = *Stenzelia*) by Williamson,[2] but was transferred in 1894 by Professor Seward[3] to *Rachiopteris*. In 1906, however, Dr. D. H. Scott[4] placed *Rachiopteris* in his genus *Sutcliffia*, and to this genus the new species here described is referred.

It is unfortunate that a detailed account of Lillie's material was never published, but, through the kindness of Mr. H. Woods, of the Sedgwick Museum, the specimens have been lent for this investigation. Much additional material has since been obtained by the writer from the Pennant Rock at various localities in both coalfields, and will be described at a later date.

The petrifactions occur either in conglomeratic bands[5] or isolated in the coarse Pennant sandstone. In the latter case there is usually a carbonaceous layer surrounding the specimens, representing the remains of the cortex and other tissues. They are found only on certain horizons within the massive Pennant Rock, so that some quarries yield no specimens while in others they are fairly common.

The preservation of the material is generally only partial, and the specimens often cannot be determined ; but the writer's collection includes interesting examples of *Calamites*, *Psaronius*, *Mesoxylon*, *Lepidodendron*, etc.

With regard to the Pennant Rock of Bristol, the late Dr. R.

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[1] Lillie, D. G., ' On Petrified Plant Remains from the Upper Coal Measures of Bristol.' *Proc. Camb. Phil. Soc.*, 1910, vol. xv, p. 411.

[2] Williamson, W. C., ' On the Organisation of the Fossil Plants of the Coal Measures.' Part 7, *Myelopteris* etc., *Phil. Trans. Roy. Soc.*, 1876, vol. clxvi, p. 1.

[3] Seward, A. C., ' On *Rachiopteris williamsoni* sp. nov., a new Fern from the Coal Measures.' *Ann. Bot.*, 1894, vol. viii, p. 207.

[4] Scott, D. H., ' On *Sutcliffia insignis*, a new type of Medullosae from the Lower Coal Measures.' *Trans. Linn. Soc.*, 1906, vol. vii, pt. 4, p. 62.

[5] A conglomerate containing fossil wood also occurs in the Pennant Rock at various localities in the South Wales Coalfield, and in the Kent Coalfield.

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Kidston[1] regarded it as belonging to "either the basement beds of the Upper Coal Measures or the upper portion of the Transition Series," but the present writer[2] has recently shown that it must be placed in the Staffordian Series of Kidston's classification. Lillie, however, in his preliminary announcement, placed the Pennant Rock of Bristol in the Upper Coal Measures (the Radstockian of Kidston), but gave no evidence in support of this correlation in the note[3] to which he refers his readers.

The Staffordian Series constitutes a new horizon for petrified plant remains. Petrifactions of Upper Carboniferous age in Britain have hitherto been described almost exclusively from the Lanarkian Series of the Lancashire and Yorkshire Coalfields. Material obtained from localities in France, on the other hand, comes chiefly from Permo-Carboniferous strata, so that the Pennant Rock specimens have the added interest of belonging to a position lying about midway between the older British and the younger French horizons.

The Medullosan petiole, portions of which are figured on Pl. I, consists of an elliptical axis the larger and smaller diameters of which are 3 and 2 cm. respectively; these measurements, however, do not represent the full size of the organ, as the outer tissues are missing. The petioles of allied plants attained a comparatively large size, that of *Sutcliffia insignis* reaching 12 cm. and *Myeloxylon* 15 or more cm. in diameter.

Transverse sections of our specimen show about fourteen vascular bundles embedded in a parenchymatous ground-tissue, the latter often being crushed and badly preserved. Typically, the bundles are surrounded by six or more fibrous strands of varying lateral dimensions. These are usually more strongly developed on that side of the bundle which is remote from the protoxylem. The mechanical strands accompanying the bundles depicted on Pl. I, Figs. 1 and 7 are not well preserved, and have not therefore been entirely included in the figures, but good examples of the tissue are seen at Fig. 4. Some of the bundles are completely or almost completely enclosed in the stereome, and occasionally two bundles which have fused or which are approaching a fusion, are embedded in an unbroken cylinder of sclerenchyma at that point. A vascular strand which is almost entirely surrounded by fibres is shown at Fig. 2. Comparing our petiole in respect of this tissue with the petioles of *S. insignis* and *S. williamsoni*, the stereome is much more strongly developed and more regularly distributed around the bundle, this constituting one of the characteristic features of *S. lilliei*. In the petiole of *S. insignis*[4] the strands often take the form

[1] Kidston, R., 'On the Fossil Flora of the South Wales Coalfield, and the Relationship of its Strata to the Somerset and Bristol Coalfield.' *Proc. Roy. Soc. Edinb.*, 1894, vol. xxxvii, pt. 3, No. 26, p. 578.

[2] Crookall, R., 'On the Fossil Flora of the Bristol and Somerset Coalfield.' *Geol. Mag.*, 1925, vol lxii, p. 398.

[3] Lillie, D. G., 'Notes on the Fossil Flora of the Bristol Coalfield.' *Geol. Mag.*, 1910, vol. vii, p. 58.

[4] Scott, D. H., *op. cit.*, 1906, pl. 9, fig. 17, pl. 10, fig. 22. It should be noted that in the leaf-base of this species the stereome is more strongly developed and more evenly distributed around the bundle than in the petioles.

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of a horseshoe only, while in *S. williamsoni* they are still less conspicuous, and, in the case of the more internal vascular strands, may be wholly absent.

One of the largest, and almost circular, groups of fibres in our specimen encloses a group of about a dozen parenchymatous elements.

The epidermis and hypodermal tissues (including the usual plates of stereome) are not present.

The parenchyma of the ground-tissue consists of comparatively large, thin-walled, polygonal cells. Numerous secretory canals, usually possessing carbonaceous contents, are irregularly distributed throughout the fundamental tissue. These are often, though not always, associated with the fibrous strands which accompany the vascular bundles. A typical canal, with contents, embedded in the parenchymatous ground-tissue is figured in transverse section at Fig. 6; two canals are included in the stereome strands given in Fig. 4, while one beginning in a group of fibres and ending in the parenchyma is shown in longitudinal section at Fig. 3. The canals are seen to consist of long tubes, and, as shown in Fig. 3, where present, the contents are often broken up into segments.

Similar secretory canals occur in the petioles of *Myeloxylon*, *Sutcliffia williamsoni*[2] and *S. insignis*,[3] and in the first named genus Seward[4] described tangentially elongated "epithelial cells" as occurring round their cavities. In *S. lilliei* several canals occur in which the presence of an epithelium is strongly suggested, but no clear instance of this tissue can be made out. I have also examined sections of the petioles of *S. williamsoni* and *S. insignis*, but in these also, while here and there structures very suggestive of epithelia occurred, no undoubted instance was found.

As in the two other species of *Sutcliffia*, some of the bundles in *S. lilliei* have a space near the protoxylem (Pl. I, Figs. 1, 7), no doubt due to a tearing of the growing tissues. Such bundles superficially resemble the collateral strands of *Myeloxylon* in which there is also a space near the protoxylem, due to the disorganisation of the phloem. The vascular bundles of *Sutcliffia*, however, are concentric in structure, although the phloem may be somewhat unequally developed round the xylem. The petiolar bundles of our specimen further agree with those of *S. insignis* and *S. williamsoni* in the absence of an endodermis. The accompanying fibrous strands form an artificial boundary to the bundles (Fig. 2).

Between these strands of stereome and the phloem occur one or two layers of parenchyma, constituting an indefinite pericycle. Secretory canals, such as are found in the ground tissue, are often

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[1] Seward, A. C., *op. cit.*, 1894, pl. 13, fig. 8.

[2] Seward, A. C., *op. cit.*, 1894, p. 210, pl. 13, fig. 3.

[3] Scott, D. H., *op. cit.*, 1906, p. 48, pl. 10, fig. 19, and de Fraine, E., 'On the Structure and Affinities of *Sutcliffia* in the light of a newly discovered specimen.' *Ann. Bot.*, 1912, vol. xxvi, p. 1035.

[4] Seward, A. C., 'On the genus *Myeloxylon* (Brong.)' *Ann. Bot.*, 1893, vol. vii, p. 10, pl. 2, fig. 10.

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embedded in the pericycle (Pl. I, Fig. 8) and sometimes in the phloem (Pl. I, Fig. 5).

The xylem of each vascular bundle consists of a small group of tracheids accompanied by xylem-parenchyma, as in the leaf-trace bundles of *S. insignis*[1] and *S. williamsoni*,[2] its presence being one of the chief distinctions between *Sutcliffia* and *Myeloxylon*. Secretory elements do not occur in the xylem-parenchyma. The (usually) single group of protoxylem tracheids is invariably peripheral.

The fact that in our petiole the outer tissues are nowhere present makes it impossible to determine the orientation of the bundles.[3] As in *S. williamsoni*, there are one or two protoxylem groups to each strand, the arrangement of the bundle being in all cases unilateral. In the leaf-trace of *S. insignis*,[4] on the other hand, there are two types of bundle, together with transitional forms: large and radially symmetrical bundles (with several protoxylem groups distributed around the outside of the wood[5]), and small and unilateral bundles (with the protoxylem to one side of the wood, in either one or two groups).

The shape of the vascular strands in these petioles is distinctive. In *S. lilliei* and *S. insignis* they are usually circular, but near a fusion they become oval, the elongation being in a tangential direction. In *S. williamsoni*, on the other hand, the bundles are typically elliptical, and the elongation is in a radial direction.[6] In both *S. lilliei* and *S. insignis* there is a marked tendency for the vascular strands to anastomose, this feature being stronger in the former than in the latter species. The protoxylem consists of narrow elements bearing spiral markings, while the tracheids of the metaxylem bear first scalariform then reticulate markings, and finally multiseriate pitting. The bulk of the xylem is composed of the last-named elements. In these respects *S. lilliei* agrees with *S. insignis*.[7]

The phloem is the most interesting tissue in these petioles. In his description of *S. williamsoni*, Professor Seward mentioned the occurrence in the outer phloem of large tubes which were often more or less encircled by a ring of small cells. In other cases the elements are represented by a group of several cells separating from a central point. While comparing these structures with the large sieve-tubes of the Marattiaceae, Seward favoured the view that they represented possible stages in a schizolysigenous process leading to the formation of small secretory canals. He pointed out that some-

[1] Scott, D. H., *op. cit.*, 1906, p. 57, and de Fraine, *op. cit.*, 1912, pp. 1047, 1048.
[2] Seward, A. C., *op. cit.*, 1894, p. 211, pl. 13, figs. 7, 8.
[3] With regard to the orientation of the bundles in *S. insignis*, Scott (*op. cit.*, 1906, p. 57) observes, "In the peripheral rank of the bundles the protoxylem is regularly directed outwards, while in those of the next inner series the orientation is often reversed," and, in describing a second specimen of this species, de Fraine (*op. cit.*, p. 261) says that the leaf-trace strands in the leaf-bases are not orientated in a definite manner.
[4] Scott, D. H., *op. cit.*, 1906, p. 57, pl. 9, figs. 14, 15, and de Fraine, *op. cit.*, 1912, p. 1047.
[5] The meristeles of the stem of *S. insignis* are radially symmetrical.
[6] See Seward, A. C., *op. cit.*, 1894, pl. 13, fig. 8.
[7] Scott, D. H., *op. cit.*, 1906, p. 61, and de Fraine, *op. cit.*, 1912, p. 1044.

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what similar elements occur in the phloem of the petioles of *Osmunda regalis*, and that in neither case is there a distinct epithelium.

With the discovery of *S. insignis* fresh evidence as to the nature of the ' bundle-canals ' became available, and Dr. Scott[1] expressed the opinion that " these little nests of cells (in *S. williamsoni*) may represent strands of small sieve-tubes more or less perfectly preserved."

The phloem in the petiolar bundles of *S. insignis* is characteristic, as, towards the outside, there is a conspicuous ring of large elements, usually separated from each other by a few small cells but sometimes contiguous. These were regarded as sieve-tubes by Dr. Scott on the grounds that the elements are sometimes contiguous, that there occur all gradations between the large elements in the petioles and the typical narrow sieve-tubes of the stems,[2] and that such a strong development of secretory canals would not be expected in the outer phloem. Dr. de Fraine agreed with this interpetation.

Turning to our specimen, there is no ring of large sieve-tubes such as forms so conspicuous a feature of the petiolar bundles of *S. insignis*, and this character at once distinguishes *S. lilliei* from that species. As in *S. williamsoni*, the phloem consists mostly of narrow thin-walled elements (which are no doubt sieve-tubes) scattered in the parenchyma, while here and there in the periphery of the phloem are larger elements, often with a fringe of small cells or group of small cells such as Professor Seward described in *S. williamsoni* as ' bundle-canals.' This similarity in the phloem of these two species is the chief resemblance between them. (Compare Pl. I, Figs. 1 and 7 with Seward's Pl. 13, Figs. 7, 8, 11 and 12.) In *S. lilliei* (in addition to instances of the ordinary secretory canals with contents) some few of the ' bundle-canals ' have carbonaceous contents. Professor Seward mentioned this feature as occurring in a single instance in the slides he examined of *S. williamsoni*, while Dr. Scott and Miss de Fraine described the sieve-tubes of *S. insignis* as destitute of such contents. But in our specimen dark contents also occur in various cells, including the tracheids (Pl. I, Figs. 1, 5 and 7). No sieve-plates can be made out on the lateral walls of either the typical sieve-tubes or of the wider ' bundle canals.' It seems certain, however, that the latter represent sieve-tubes in various stages of decay, and it is interesting to note that in *S. insignis* those sieve-tubes which are somewhat isolated in the parenchyma may also be invested by a series of small cells.

The chief points of resemblance and difference between the various known petioles of *Sutcliffia* are tabulated below. It is evident that, while in certain features our specimen resembles both *S. williamsoni* and *S. insignis*, it cannot be united to either. I

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[1] Scott, D. H., *op. cit.*, 1906, p. 61.

[2] It should be pointed out that the sieve-tubes in the steles and meristeles of *S. insignis* are not of large diameter, as are those in the outer phloem of the leaf-traces and petioles.

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have therefore named the specimen after Mr. D. G. Lillie, who discovered it.

Petioles of *Sutcliffia*.

	S. williamsoni	*S. lilliei*	*S. insignis*
Structure of bundle	Concentric, protoxylem exarch, xylem-parenchyma present	Concentric, protoxylem exarch, xylem-parenchyma present	Concentric, protoxylem exarch, xylem-parenchyma present
Shape of bundle	Elliptical, with more or less marked radial elongation	Circular or oval, with slight tangential elongation	As in *S. lilliei*
Sieve-tubes	Small and scattered	Small and scattered	Large and conspicuous, in a discontinuous ring
Stereome accompanying bundles	Few strands, especially round internal bundles	Very strongly developed, sometimes completely encircling bundle	Several strands, often in an arc on one side of bundle only
Fusion of bundles	Occasional	Very frequent	Frequent
Horizon	Lanarkian Series	Staffordian Series	Lanarkian Series

My thanks are due to Mr. W. N. Edwards, B.A., of the British Museum (Natural History), for facilities in examining the sections of *S. insignis*, etc. in the Scott Collection, and I gladly record my great indebtedness to Dr. D. H. Scott, F.R.S., who has most kindly allowed me to consult him on this and other specimens.

Diagnosis.

Sutcliffia lilliei n. sp.

Petiole with circular bundles in transverse section. Bundles frequently fuse, and near a fusion are slightly tangentially elongated. Each vascular strand enclosed in a more or less broken cylinder of sclerenchyma. Sieve-tubes comparatively small and somewhat scattered.

Horizon. Staffordian Series.
Locality. Staplehill, Bristol.

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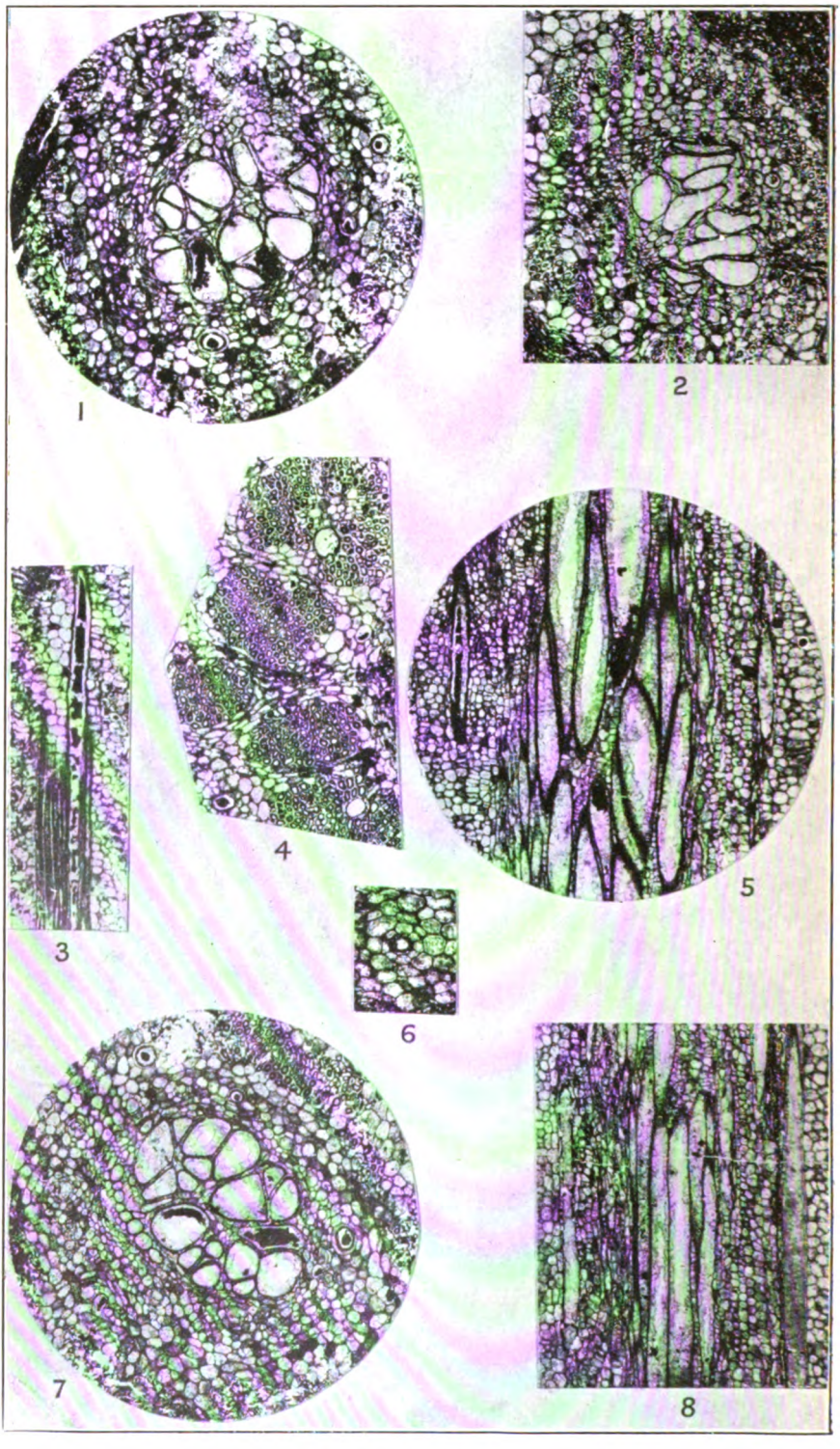

Sutcliffia lilliei n.sp.

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EXPLANATION OF PLATE

Fig. 1.—Transverse section of a vascular bundle. The cylinder of xylem, with peripheral protoxylem, is completely surrounded by phloem. Outer phloem with three secretory canals (with contents). Stereome is somewhat decayed and not entirely included in the figure. Several 'bundle-canals' are well shown in the outer phloem. x 23.

Fig. 2.—Transverse section of bundle which is almost completely encircled by stereome. Latter is more strongly developed on that side of the bundle which is remote from the protoxylem. x 23.

Fig. 3.—Longitudinal section showing secretory canal embedded in a group of fibres below and in the parenchymatous ground-tissue above. The carbonaceous contents are broken into segments. x 23.

Fig. 4.—Transverse section passing through several well-preserved strands of stereome, two of which contain a secretory canal. x 23.

Fig. 5.—Longitudinal section of a bundle showing central xylen with phloem on each side. To the left and right of the bundle, in the ground-tissue, is a secretory canal. x 23.

Fig. 6.—A secretory canal, with contents, in the ground-tissue: transverse section. x 23.

Fig. 7.—Transverse section of a bundle. The nests of small cells surrounding some of the sieve-tubes are well shown. Stereome badly preserved. x 23.

Fig. 8.—Longitudinal section of bundle showing tracheids and phloem, and, to right and left, in the ground tissue, a secretory canal. x 23.

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APPENDIX XII

The Use of the Torsion Balance in the Investigation of Geological Structure in South-West Persia

By W. F. P. McLintock, D.Sc., and J. Phemister, M.A., B.Sc.

Text-figures 1 to 22 (*b*).

Introduction

Considerable attention has been directed in recent years to the investigation of geological structure by geophysical methods, more particularly by the method of gravitational surveys made with the torsion balance as designed by Eötvös. In such surveys the rates of variation in the value of the force of gravity are determined usually at a network of positions over the area surveyed. The variations in the value of gravity at points in the same neighbourhood are due in part to the unequal vertical distribution of light rocks and heavy rocks in the earth's crust and, when the component of the variation due to other influences can be evaluated, we obtain by subtraction the effect due to the underground distribution of mass. From this, conclusions may be drawn regarding the geological structure.

Much of the recent and important work done with the torsion balance has been carried out by commercial firms interested in the search for oil and ores, and the results. with details of the methods by which they are obtained, in most cases have not been published. In consequence considerable uncertainty regarding the value of the torsion balance in the elucidation of geological structure exists amongst geologists. Through the kindness of Sir John Cadman and the Anglo-Persian Oil Company the Geological Survey Board was invited to send two officers to investigate in the field the work being carried out in Persia by the company's geophysical staff, and in March, 1926, the writers proceeded to south-west Persia, where a gravitational survey was in progress. A report was subsequently made to the Geological Survey Board who, believing that it contained information of general interest to geologists and with the consent of the Anglo-Persian Oil Company, instructed us to prepare it for publication.

We wish, at the outset, to make it clear that the results, the method of plotting them and, in large measure, the deductions made from them, as set forth in the sequel, are the work of the geophysical staff of the Anglo-Persian Oil Company, Mr. W. R. Macdonald, Dr. J. H. Jones and Mr. R. Davies, who have placed unreservedly all their observations at our disposal. We are responsible only for

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the compilation of the paper, for the general observations and for the appendix which, it is hoped, may prove useful to geologists unacquainted with the torsion balance and the principles on which it works. Dr. J. H. Jones has in preparation a detailed study of the results of the survey over the Ahwaz Gap (p. 175). It contains all the relevant mathematical analysis and will be published in due course. Meanwhile we have been permitted to set out his general conclusions.

The Eötvös Torsion Balance

In 1888 Baron Roland von Eötvös described the torsion balance that bears his name and subsequently modified it to the type now used in gravitational surveys. By means of this instrument the variations in the value of gravity per centimetre along the horizontal can be measured with an accuracy of 1×10^{-9} c.g.s. unit. The balance consists of an aluminium beam suspended by a fine torsion wire. At one end of the beam a weight is fixed and from the other end a weight is suspended by a wire. Owing to the difference in position of the weights both in the horizontal plane and in the vertical direction there is in general a difference both in magnitude and direction between the forces of gravity on the two weights. The position in which the beam comes to rest depends on these differences (p. 186). The beam is set in several arbitrary directions and the position of rest relative to a scale fixed to the balance casing noted in each case; for the determination of the various quantities which can be calculated from the balance-readings it is necessary to know these readings in five different azimuths. Owing to the long period of swing of the balance, about one hour must elapse before the position of rest is reached and consequently with a single beam system as described, observations at any one station take at least five hours. In order to shorten this period the modern instrument consists of two balance systems arranged parallel to one another but so that the end of the first beam carrying the wire to which the lower weight is attached lies adjacent to the end of the second beam to which the upper weight is fixed, and vice-versa. The two systems are fixed side by side on a pedestal so that they can be rotated together into various azimuths. With such an instrument the positions of rest need only be observed in three azimuths, and therefore only three hours are necessary to obtain sufficient data for calculation.

A full description of the most modern type of balance will be found in a small handbook[1] published by Messrs. Oertling, Ltd.

In the present paper it is not proposed to deal with the mathematical theory of the torsion balance, but it is necessary at the outset to introduce certain of the terms constantly employed in the consideration of the results of gravitational surveys and to indicate their significance. The measurements made in the course of torsion balance surveys are the magnitude and direction of the Gradient of Gravity, the Horizontal Directing Tendency, and the directions of principal

[1] 'The Eötvös Torsion Balance,' 1926, L. Oertling, Ltd., London.

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curvature of the Level Surface at each station of the survey. The values of these obtained from the balance observations are the resultant values arising from the following causes :—

(1) The departure of the shape of the earth from a truly spherical form.
(2) Variations in level and in superficial distribution of mass in the neighbourhood of the balance.
(3) The variable manner of distribution of rocks of different specific gravity in the crust of the earth.

The effect due to the first of these three causes depends only on the latitude of the station and is calculated from a formula.

The effect due to variations in level and in superficial distribution of mass depends upon the presence of hills and valleys and of minor surface irregularities, and also upon the existence of ditches, walls, holes, or surface-boulders near the balance station. The calculation of this effect is made under four heads :—

(1) The *terrain effect*, that is, the influence due to changes of level of the surface of the ground within a radius of 100 feet from the balance.

(2) The *topographic effect*, that is, the influence due to the altitude changes within a region beyond 100 feet and within 1,000 feet of the balance.

(3) The *cartographic effect*, that is, the effect of varying mass distribution in hills and valleys lying between 1,000 feet and from 2 to 5 miles from the balance station.

(4) *Special effects*, including effects due to walls, ditches, etc.

Assuming that these effects have all been calculated we subtract their sum from the values given by the balance. The remainder is the effect due to the mode of distribution of mass beneath the surface of the ground, that is, due to the subterranean geological and topographical structures.

Throughout the following pages we shall assume that all influences on the magnitude and direction of Gradient and Horizontal Directing Tendency other than those due to the underground structure, have been allowed for ; we may therefore conceive the balance measurements to have been made over an ideal smooth spherical earth, at the surface of which the magnitude and direction of the force of gravity vary only on account of the geological structure in the crust.

By the term *Level Surface* used in connection with gravitational surveys is meant a surface at every point of which the direction of the force of gravity is at right angles to the surface. If in our ideal smooth spherical earth there were no folding, faulting nor intrusion, the forces of gravity would be everywhere directed towards the centre of the earth ; the level surfaces would therefore be concentric spheres. Should a fold disturb the concentric shell arrangement of the rocks in the crust, so that, for example, heavy rocks are brought

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closer to the surface in the core of the fold, then the forces of gravity will be directed a little towards the core of the fold. The level surface will therefore be curved[1] over the fold axis and will correspond to the fold in shape; in other words the directions of greatest and least curvature of the fold will also be the directions of greatest and least curvature of the level surface. These directions are at right angles and are determined by the balance; one of them is the direction referred to, for conciseness, as the direction of horizontal directing tendency (see Appendix, p. 187). The strike of the rocks is the direction of least curvature (numerically); therefore the strike will be indicated by the torsion balance results.

The magnitude of the *Horizontal Directing Tendency* (briefly H.D.T.) is proportional to the difference between the curvatures of the level surface in the directions in which they are greatest and least

The degree of curvature of the level surface varies with the steepness of the fold and with the density of the core rocks relative to the upper rocks. The H.D.T. therefore indicates to some degree the steepness of the folding.

Gradient of Gravity.—In Fig. 1 let the value of the force of gravity on unit mass at a point A be g_A c.g.s. units. Draw with radius 1 cm. a circle in the horizontal plane at A. Then in general the value of the force of gravity will vary from point to point on the circumference of the circle. Suppose that the greatest value occurs at B and is there g_B c.g.s. units. Then the gradient of gravity (referred to hereafter briefly as gradient) is $g_B - g_A$ and $\overline{A\,B}$ is the direction of the gradient. $\overline{A\,B}$ will be directed towards the heavy matter which is responsible for the increase. If the increase in the value of gravity is due, for example, to the rising towards the surface of heavy rocks in the core of an anticline, the gradient will be directed towards the axis of the anticline. Therefore as the axis of the anticline is crossed the gradients must change direction. At the axis of the anticline the gradient must therefore have zero value.[2]

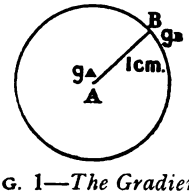

FIG. 1—*The Gradient of Gravity*

The magnitude and direction of the gradient are both calculated from the torsion balance observations.

From the definition of the gradient as the increase in gravity by so many units per centimetre it follows that if we know the

[1] The apparent contradiction in this statement is at once removed when it is realised that a level surface is not in general a plane surface. For example, the surface of a calm sea is a level surface yet it is a curved surface. A less confusing name for a level surface is equipotential surface. An equipotential surface of gravity is such a surface that no work is done by or against gravity in moving a mass from any point of the surface to any other point of the surface. Since the force of gravity is normal to the level surface at any point of it, a mass moved along a level surface from one point to any other point on the same surface is always being moved at right angles to the direction of the force of gravity. No work by or against gravity is done during the displacement. Therefore the level surface and the equipotential surface are the same.

[2] Provided the anticline is symmetrical and the axis does not pitch.

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gradient at two adjacent stations and the distances between the stations we can calculate the actual difference between the force of gravity at the two stations provided they are sufficiently close to justify the assumption that the force of gravity is varying uniformly between them. If the survey is made along a line we can, starting from any one station, calculate the difference of gravity between the value at this station and that at any other station. In this way we can plot a curve known as the " delta g" (Δg) or *Gravity Anomaly* curve showing the numerical value of the force of gravity at any point along the traverse relative to the value at any of the other stations. In the case of a simple symmetrical anticline with heavy core the greatest value of the force of gravity will be vertically above the crest and will be least far out on the flanks. The gravity anomaly curve will therefore show its maximum above the crest and its shape will correspond with that of the fold.

In summary the torsion balance gives us :—

(i) the magnitude of the gradient,
(ii) the direction of the gradient,
(iii) the magnitude of the H.D.T.,
(iv) the directions of greatest and least curvature of the level surface.

For general elucidation of the structure the directions of gradient and of greatest and least curvature of the level surface are the most important.

For estimation of a first approximation to the shape of the structure the gravity anomaly curve obtained from the values of the gradients is necessary.[1]

For estimation of depth and difference of specific gravity the values of gradients (and, for corroboration, values of H.D.T.) at as many points as possible are necessary, so that interpolation on the gradient curve may be accurate.

Diagrams illustrating the above remarks will be found in the appendix.

In pages 173–183 sufficient data will be given to show that there is good agreement between information supplied on the one hand by torsion balance surveys, and on the other by ordinary geological observations, in the case of simple structures at no great depth such as are common in south-west Persia.

ACCOUNT OF THE RESULTS OBTAINED BY THE GEOPHYSICAL STAFF OF THE ANGLO-PERSIAN OIL CO.

It is usual in making a torsion balance survey to plan a network of stations arranged as far as possible according to the available

[1] Since in this paper the structures considered are assumed to be very large along the strike, no use has been made of isogam lines, i.e., lines along which the numerical value of the force of gravity is the same, and therefore we have omitted any reference in the text to them. The gravity anomaly curve along a straight traverse is the section along the traverse across the isogam map of the area.

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geological evidence, so that the general structure may be approximately found in those directions which are probably most important. In south-west Persia the problem is much simplified, for the geological structures run in lines directed north-west to south-east so consistently that even in alluvium-covered country it can be assumed that any structure which may be revealed by the balance will have its axis roughly in that direction. In other words, what is normally a multi-directional problem is in Persia simplified to a uni-directional one. In the area to be surveyed a single line is selected at right angles to the strike of the nearest geological structures. A traverse along this line is completed, and if necessary observations are made at additional stations. This method has proved in practice quite successful, and the strikes of underlying structures deduced from the results of the torsion balance surveys have agreed with the strike of the rocks in the adjacent exposures.

Three such traverses will now be briefly described, and special consideration given to the interesting results obtained in numbers (2) and (3).

(1) The Jabal Sannam-Ahwaz Traverse, 95 to 100 miles long; stations 2 miles apart.

(2) The Ahwaz Gap Traverse, 1½ miles long; stations at varying distances apart, occasionally as little as 40 to 50 yards.

(3) The Mishdakh Traverse, 8½ miles long, stations ¼ to ½ mile apart.

(1) *The Jabal Sannam-Ahwaz Traverse.*

This traverse was run from Jabal Sannam on the south-west to Ahwaz on the north-east. Ahwaz lies on the River Karun almost 70 miles north-north-east of its junction with the Shatt el Arab. Jabal Sannam is about 30 miles south-south-west of Basra. The most south-westerly outcrops of the folded Tertiary sediments of south-west Persia occur at Ahwaz. South-west from that town across the great plain at the head of the Persian Gulf no rock is exposed until Jabal Sannam is reached, nearly 100 miles away. The traverse under description was made with the object of detecting any geological structure concealed under this broad alluvial belt.

The results of the survey are given as curves in Fig. 2 showing the components of gradient and H.D.T. values along the line of traverse. Both curves indicate at the north-east end of the traverse a sharp fold. This is the Ahwaz anticline already known from surface geology. It is investigated in detail in the survey next described (pp. 175–181).

South-west of Ahwaz the structure is a simple, very shallow syncline, the lower heavy rocks rising gently towards the south-west. This can be readily deduced from the curves which are so drawn that gradients plotted as positive denote gradients directed

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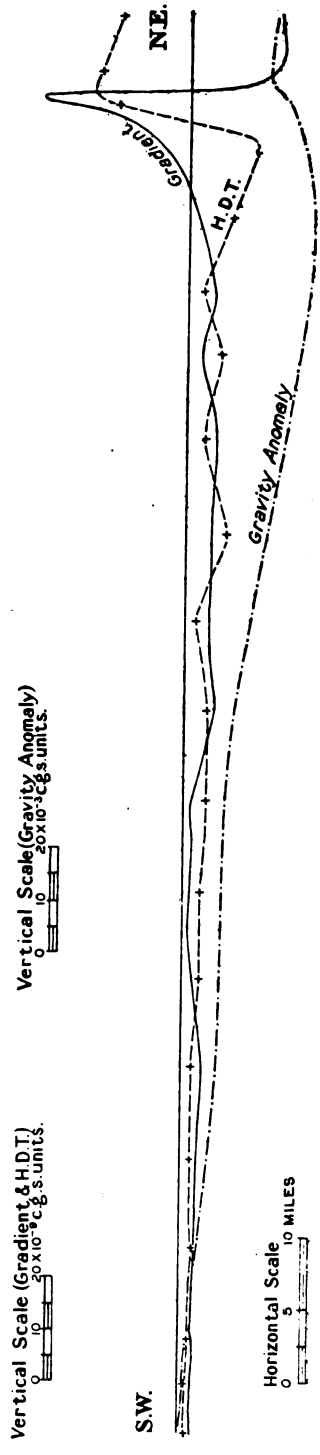

FIG 2—*The Jabal Sannam-Ahwaz traverse.*

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towards the north-east, negative gradients denote gradients directed towards the south-west; whilst positive H.D.T. values indicate that the structure is anticlinal, negative values that it is synclinal (see pp. 187–188). Large values of gradient and H.D.T. combined with rapid variation in the values indicate a steep structure.

The third curve of Fig. 2 is the gravity anomaly or Δg curve constructed by integration of the gradient curve. The Δg curve shows rapid variations in the value of g over the Ahwaz fold, and to the south-west shows constant gradual increase in the value of g owing to the slow constant rise of the heavier rocks beneath the plain.

(2) *The Ahwaz Gap Traverse.*

This traverse and the following one were made with two instruments, a Rybar model used in the previous survey, and a standard Eötvös instrument by Süss. Each day two stations were set up and terrain and other corrections calculated; at night observations were made on the two instruments. The simultaneous use of two instruments makes it possible to detect any abnormal reading arising either from instrumental error or from local subterranean irregularity. Repetition on the other balance of the observations at the station yielding the abnormal results will indicate immediately to which cause they are due.

The Ahwaz Gap traverse was made through a large gap in the Ahwaz ridge, 8 miles east-south-east of Ahwaz. A large number of stations were investigated, and it was thus possible to determine the gradient and H.D.T. curves with sufficient accuracy to enable them to be compared with theoretical curves derived from ideal structures.

The sketch-map (Fig. 3) on p. 176 shows the surface geology of the area across which the traverse was made, the topography and the positions of the stations. It is clearly seen how the line of traverse was selected at right angles to the strike of the country. Where the line of traverse intersects the River Malih (dry) there is a depression, to avoid which the line was shifted $\frac{1}{4}$ mile to the south-east. This line again intersected the river, necessitating a second displacement to the north-west as shown in the map. The results obtained from these three parallel traverses are considered as those which would have been obtained along one single traverse, the justification being that changes along the strike are small on account of the gentle pitch of the fold.

The curves in Fig. 4 show the results obtained in this survey. The position of the geological axis together with the scale is sufficient to relate points on the horizontal axis and corresponding points on the line of traverse shown by the sketch-map. The ordinates of the gradient curve are the components of the gradient along the line of traverse, and are plotted as positive when the gradient is directed from left to right. The curve shows that from A to B on the line of traverse, the value of gravity is, on account

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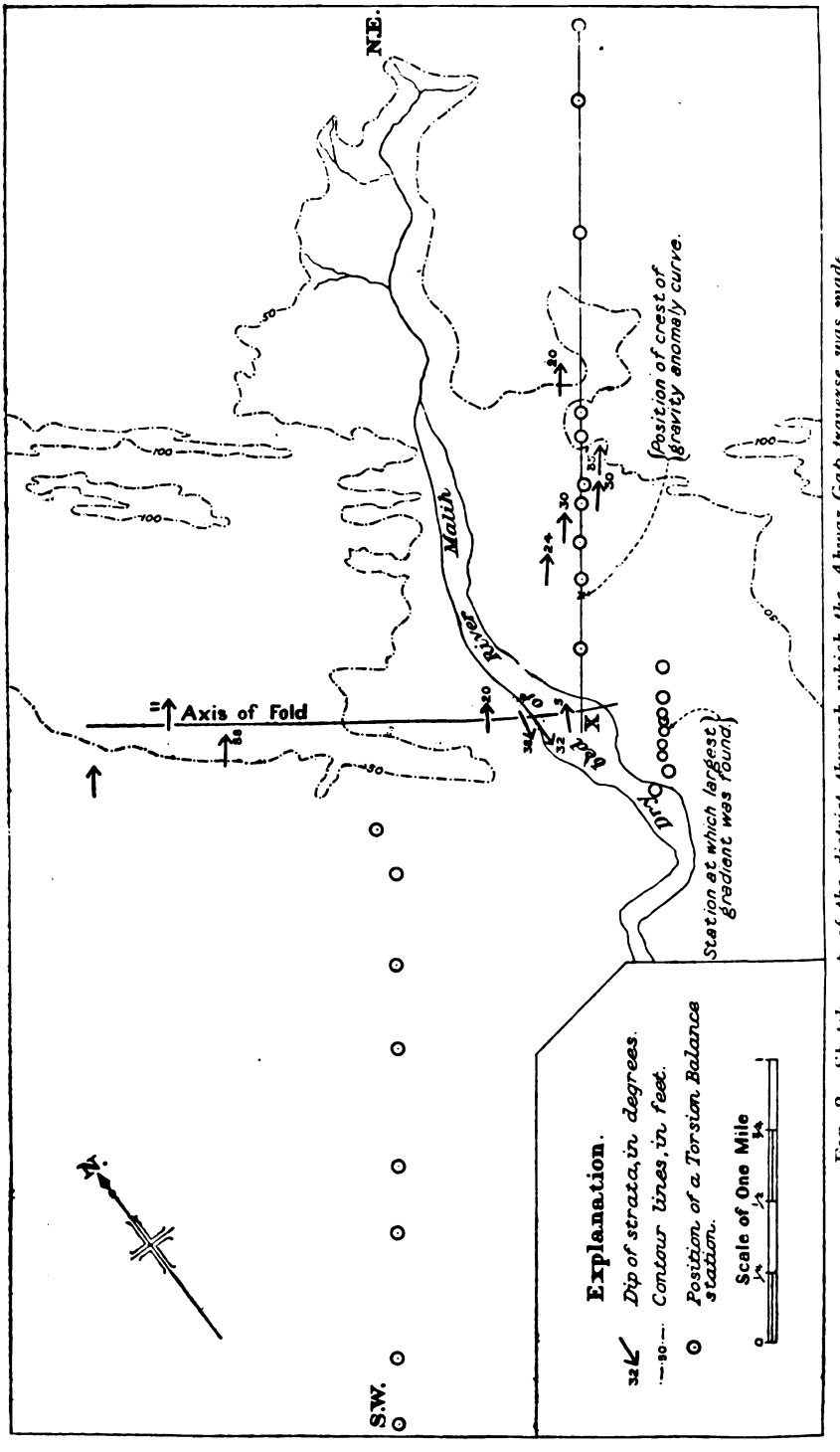

FIG. 3—*Sketch-map of the district through which the Ahwaz Gap traverse was made.*

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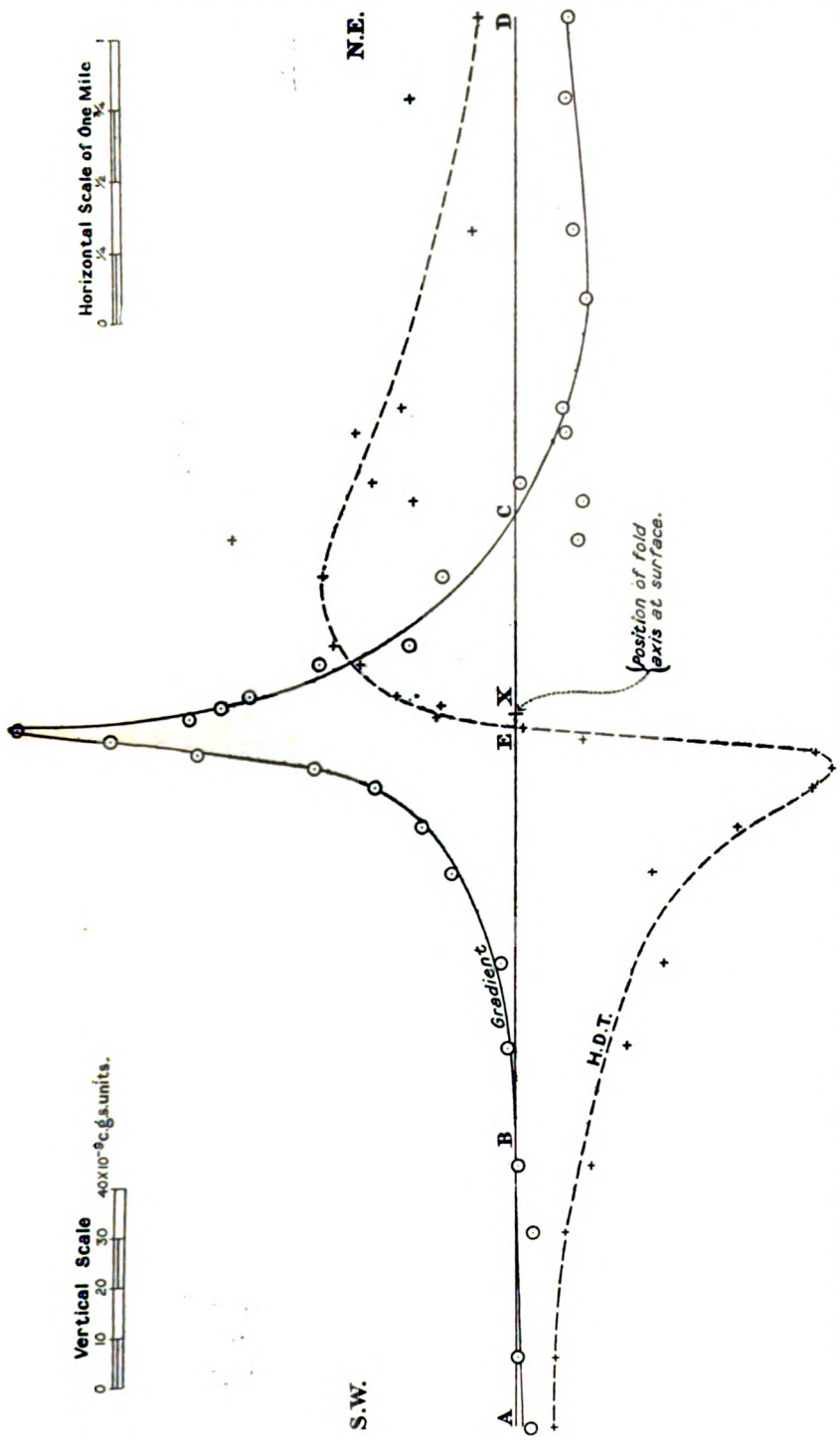

FIG. 4.—*The Ahwaz Gap traverse. Curves showing components of gradient and H.D.T. along the line of traverse.*

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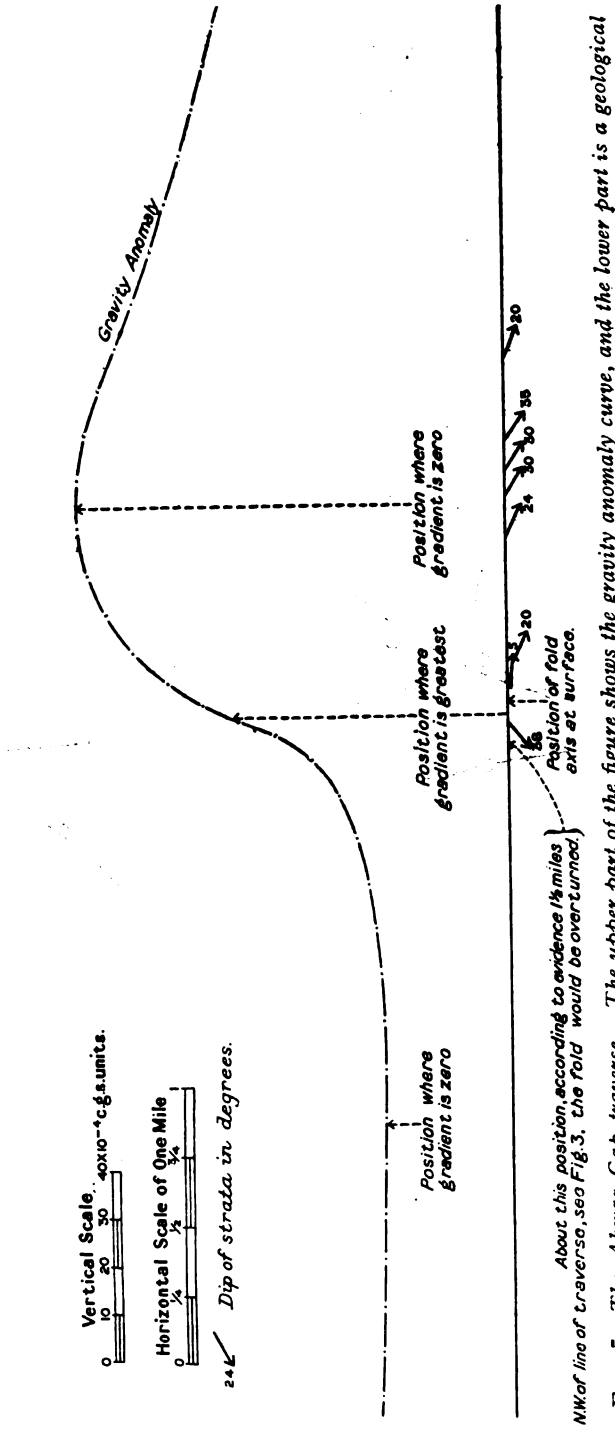
Gravity Anomaly
Vertical Scale
40x10⁻⁶c.g.s.units.
0 10 20 30
Horizontal Scale of One Mile
0 ¼ ½ ¾ 1
24 Dip of strata in degrees.
Position where gradient is zero
Position where gradient is greatest
Position where gradient is zero
Position of fold axis at surface.
About this position, according to evidence 1½ miles N.W. of line of traverse, see Fig. 3, the fold would be overturned.
20
55
30
30
24
20

FIG. 5—*The Ahwaz Gap traverse. The upper part of the figure shows the gravity anomaly curve, and the lower part is a geological section along the line of traverse.*

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of some underground structure, decreasing, from B to C it is increasing, and from C to D it is again decreasing. The very rapid change of gradient between B and C indicates that the structure is a steep fold or possibly a fault.

The ordinates of the broken curve of Fig. 4 give the values of the components along the line of traverse of the H.D.T. When the ordinate is positive the equilibrium position (see Appendix, p. 187) of a freely suspended beam tends to be at right angles to the line of traverse, and a negative ordinate indicates that the equilibrium position tends to be parallel to the line of traverse. The curve shows a very sudden change from parallelism to the line of traverse for points left of E to a position at right angles to the line of traverse for points right of E. The sudden change indicates a rapid change from a synclinal fold left of E to an anticlinal fold right of E.

The gravity anomaly curve plotted in Fig. 5 is constructed by integration of the gradient curve. It shows the difference in value of the force of gravity along the traverse due to the underground structure. Like the gradient and H.D.T. curves it too indicates a steep fold. Where the gradient is greatest, that is where the shape of the gravity anomaly curve changes from concave to convex, the H.D.T. is zero or approximately so. The lower part of Fig. 5 shows, in the form of a geological section, the dips observed along the line of traverse. Comparison of the upper and lower parts of this figure shows that the gravity anomaly curve does not coincide with the fold either in position or in shape, but is a rough approximation to the shape of the fold.

To interpret the results obtained in this traverse it is necessary to know the types of curves yielded by various theoretical structures. Reference to the appendix (pp. 189–192) will show the types of curves for gradient, H.D.T., and gravity anomaly yielded by faults and folds. Comparison of the gradient curve of Fig. 4 with that of the fault shown in Fig. 19 (p. 192) indicates a general resemblance between the two. They differ however in that the gradient curve of the Ahwaz structure changes sign, in this respect resembling the curve due to the anticlinal structure shown in Fig. 20 (p. 192). It thus appears that the Ahwaz fold is in character intermediate between a fault and an anticline.

On these lines Dr. J. H. Jones has calculated theoretical curves for asymmetric anticlines, and he finds, so far as his calculations have been carried out, that a close approximation to the curves of the Ahwaz structure is given by an asymmetric anticline of which one limb is vertical while the other dips at a gentle angle. The gradient and H.D.T. curves of such a structure are shown in Fig. 6. The value of the specific gravity difference (which is a constant factor of all the ordinates) is chosen so that the maximum gradient due to the structure will be equal to the maximum gradient over the Ahwaz fold. Comparison of Figs. 4 and 6 shows that the curves are very similar. An important point of detail, however, is that the theoretical gradient curve is steeper on the right than on the left, while

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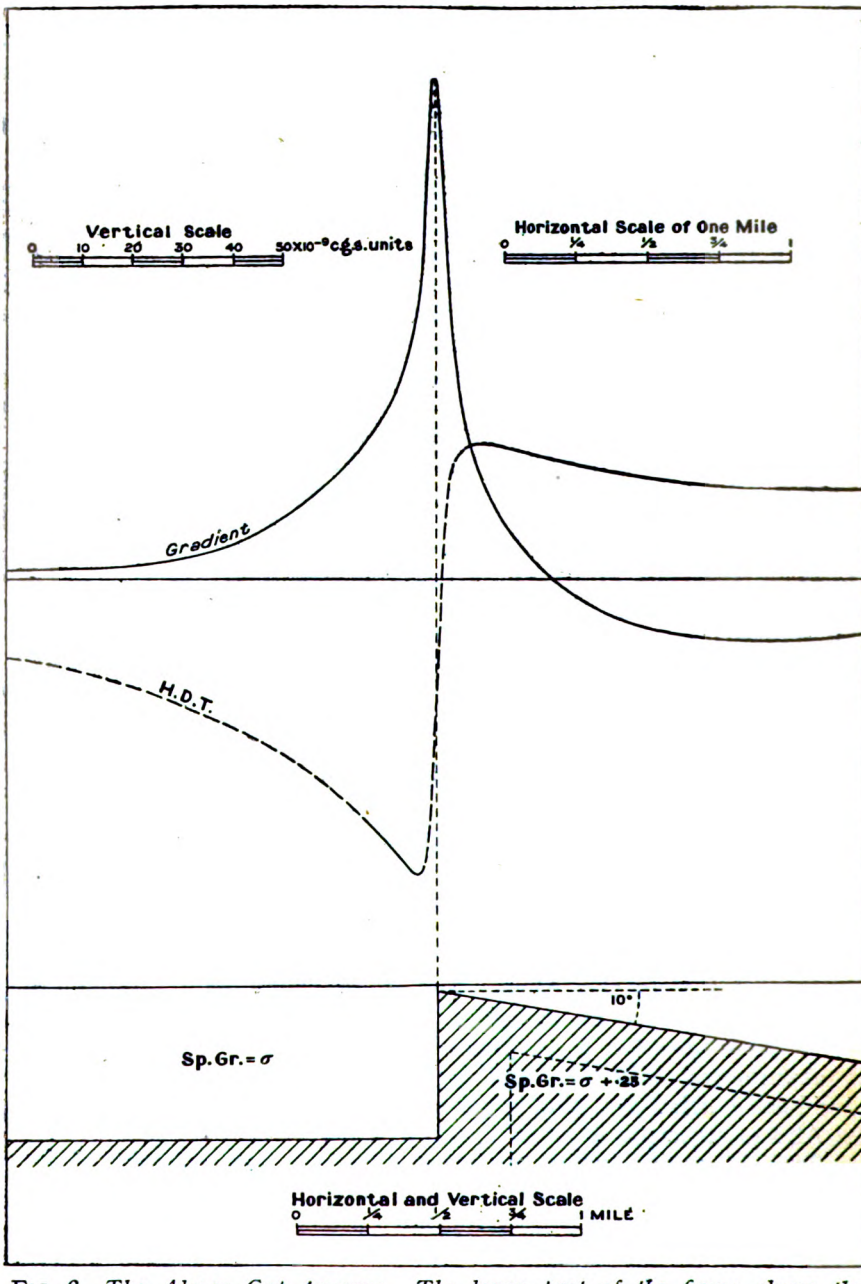

FIG. 6—*The Ahwaz Gap traverse. The lower part of the figure shows the hypothetical structure which yields the gradient and H.D.T. values shown in the upper part of the figure.*

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in the experimental curve the reverse is the case. If we convert the vertical limb of the theoretical structure into an isoclinal limb the right-hand side of the theoretical gradient curve is flattened and the left-hand side steepened, so that the similarity between the two curves is now more marked (see Fig. 22 (a), p. 194).

Dr. Jones, however, points out that if the effect due to the presence of a second, deeper, differential gravity surface (dotted line of the lower part of Fig. 6) be taken into account, the result will be to flatten the right-hand side of the gradient curve very much more than the other side is steepened, and he considers that the structure shown in Fig. 6 containing a shallow and a deep differential surface is therefore a truer representation of the actual occurrence. In a forthcoming paper by Dr. Jones the problem will be treated in detail, mathematical analysis being applied to the experimental curves in order to determine the depths of the critical parts of the fold and the differences of specific gravity above and below the differential surfaces.

It remains to review shortly the field evidence of geological structure. The sketch-map (Fig. 3) shows a fold whose north-east flank dips somewhat steeply near the axis but flattens out towards the north-east. The south-west limb has a steep south-west dip close to the axis and is slightly overturned at a short distance from the axis. Broadly considered, then, the field evidence is in agreement with the results obtained by means of the torsion balance. The visible geological axis of the fold intersects the line of traverse at the point X, on the sketch-map (Fig. 3) and on the experimental gradient curve (Fig. 4), that is about $\frac{1}{16}$ mile distant from the position of maximum gradient and towards the gently dipping flank of the fold. The maximum gradient (Fig. 6) due to the first differential surface of the theoretical structure is practically above the crest but tends to be on the steep flank. If the fold were isoclinal the maximum gradient would be still further away from the crest towards the steep side.

Although there are discrepancies in detail, e.g., between the dips in the theoretical and in the actual structures, yet in view of the general agreement one must regard this survey as a successful test of the usefulness of the Eötvös torsion balance. Whether the theoretical modifications are to be trusted so far as to allow calculations of depth and specific gravity differences based upon them to be considered practically useful is a question to be answered only by boring (see p. 185). Dr. Jones is, however, in possession of certain information from boring which leads him to believe that the experimental gradient results are sufficiently accurate to allow approximate depths of the second differential surface to be calculated and to permit correlation of the differential surfaces with definite geological horizons.

(3) *The Mishdakh Traverse.*

This traverse was, as usual, run at right angles to the strike of

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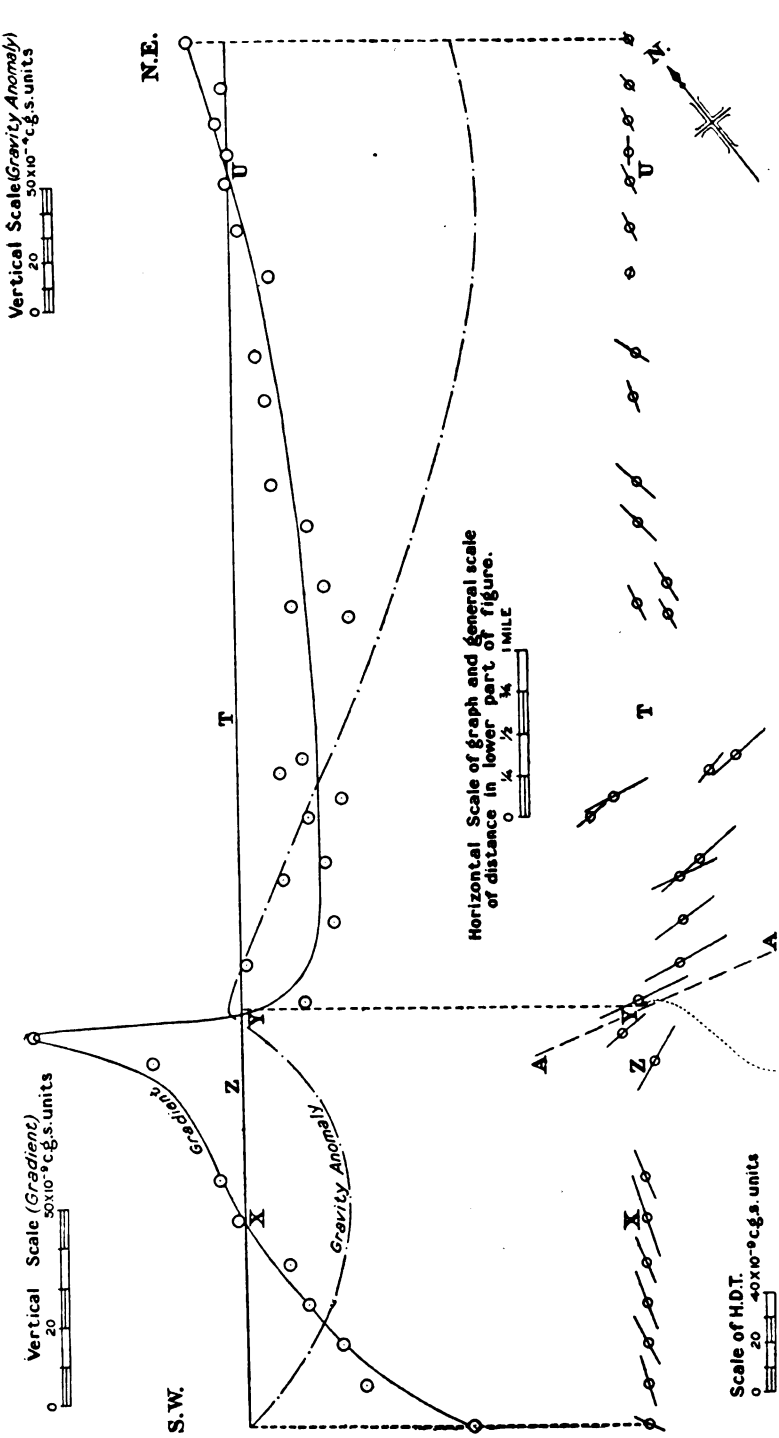

FIG. 7.—*The Mishdakh traverse. The upper part of the figure shows the components of gradient along the line of traverse and the corresponding gravity anomaly curve. The lower part of the figure shows in plan the horizontal directing tendency at the stations.*

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the country as determined from the Mishdakh range. It was made across the plain on the north-east of the Mishdakh range about 60 miles north-west of Ahwaz in order to investigate the possibility of folds in that direction. In this case again there are surface indications from which it is possible to check the torsion balance results by means of observed geological facts.

The curve of Fig. 7 shows the components of the gradients resolved along the line of traverse. The lower part of the figure is a plan of the traverse showing the magnitude and direction of the H.D.T. The actual gradients have not been drawn as the plan would then have become very intricate, but it should be stated that the average inclination of the gradients to the line of traverse is about 20°, indicating that the line of traverse is not at right angles to the strike. From the plan showing the H.D.T. directions, we find that they fall into two groups of almost parallel lines nearly at right angles to one another and inclined at about 25° and 115° to the line of traverse. The directions both of gradient and H.D.T. agree in indicating a structure across which the line of traverse passes obliquely.

The line A A (Fig. 7) is drawn through the position, Y, of zero gradient. The group of H.D.T. values making a high angle with the line of traverse corresponds to those gradients which are directed towards the line A A. If the lower rocks in the fold have a higher specific gravity than the upper rocks, this line A A represents, in plan, approximately the position of the axis of an anticline, for the gradients all point towards it, indicating that the heavier material is approaching the surface closest vertically below this line: also the H.D.T. directions are parallel to it, indicating that the level surface and therefore the fold is convex upwards. The greatest H.D.T., showing the crest of the level surface, is approximately at Y. To the left of Y the component of H.D.T. along the traverse line diminishes very rapidly and soon changes direction, about Z, indicating a rapid transition from an anticlinal to a synclinal structure. To the left of Y the fold must be very steep. The component of the gradient becomes zero again at X, that is, the gradients at points adjacent to X point away from X and therefore X is an approximate position for the axis of the syncline already indicated by the H.D.T. directions to the left of Z. On the extreme left of Fig. 7, it appears as if the H.D.T. directions were again about to swing through 90° indicating that the dominant structure is once more anticlinal. This anticline, as a matter of fact, is the Mishdakh anticline to which the extreme south-west station is as close as it was possible to go without necessitating a survey of the Mishdakh range in order to calculate cartographic corrections.

Geological evidence in the field shows an anticlinal axis intersecting the line of traverse at the point indicated in Fig. 7.

To the right of Y the results given by the balance are more complicated. In a broad way the fold falls from its crest, approximately at Y, as an anticlinal slope to somewhere about T. The

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H.D.T. directions then show that the level surface is concave upwards and remains so to the north-east limit of the traverse; the gradients change direction at U and there is therefore a synclinal structure north-eastwards from T with its trough approximately beneath U.

Superimposed on the effects due to this general structure, however, there are apparently many minor effects of a locally intense character causing the very irregular variations in gradient values seen in Fig. 7. These variations may be due to subsidiary foldings of the main structure with local sharp pitching, or may be due to irregular subterranean topography beneath the alluvium of the plain.

It is clear that much experience is necessary to enable one to form a mental picture of what may be happening, and that to disentangle the major structure from the minor ones and interpret each is a task involving in the first place great accuracy and reliability of the results, in the second place an abundance of stations to enable the minor structures to be clearly shown up, and in the third place, if numerical deductions have to be made, a high degree of mathematical facility.

The reliability of the results naturally depends largely upon the evaluations of the corrections necessary on account of the unequal distribution of surface matter. It is generally considered that though this may involve a very great amount of tedious calculation it can usually be accurately effected in flat or smooth country. If the minor structures detected by the balance are geological structures they may be expected to vary steadily and give effects which will indicate their presence. If they are, however, of the nature of preglacial surface topography, or are due to varying specific gravity of the terrain material they may, on account of their proximity to the balance, give large and incoherent effects which may obscure to a large extent the geological structure. In the absence of experimental tests over country covered by glacial drift nothing but such general opinions can be expressed.

Emphasis should also be laid on the necessity for collecting and using all possible geological data, both in order to plan the survey to the best advantage, and to have a dependable guide to the interpretation.

REMARKS ON THE UTILITY OF THE TORSION BALANCE

The results described in the foregoing pages show that the general structure of an area can be elucidated by means of the torsion balance, provided that the structure is simple. The approximate positions of the main axes of folding can be determined as well as the relative steepness of the flanks of the folds. Detailed results, such as depths and dips, calculated from balance readings, may be regarded as approximately correct provided that the country is geologically simple, as it is in the Ahwaz district, and that the results are determined from consistent readings obtained at a large

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number of stations in the critical localities. The value of a depth determination naturally depends on the possibility of correlating the specific gravity differential surface with a known geological horizon. As mentioned above, Dr. Jones has evidence that definite geological horizons may be expected to occur at depths roughly corresponding to those of the differential surfaces in the theoretical representation of the Ahwaz fold.

With reference to Dr. Jones' view that, by modifying the effects due to a shallow differential surface by those due to a deeper surface, he obtains a theoretical structure yielding a gradient curve of the same shape as the experimental curve of the Ahwaz fold, it may be suggested that a steep ripple in the gently dipping flank of the shallow differential surface may produce a similar result. The presence of such a ripple would seriously affect any numerical deductions made on the assumption that the only modification present is a second, deeper, differential surface. Pitch of the fold axis, when the stations are not all collinear (see sketch-map, Fig. 3, p. 176), must produce small inconsistencies in the gradient values. These deviations from the values obtained from a traverse in which all stations are collinear will probably not affect calculations relating to a shallow differential surface but will render of doubtful value numerical deductions relating to a deeper surface.

It must be remembered that the traverses described above have been carried out in districts extremely suitable for gravitational survey. Topographic and cartographic effects are frequently negligible and terrain corrections are often very small, whilst the structures studied are intense and produce effects on the balance outweighing any small effects due to local disturbances. The success of the balance in tracing even gentle structures in such conditions is shown by the fact that the survey from Ahwaz to Jabal Sannam indicated the existence of a geosyncline between the Persian foothills and the Arabian foreland, the conception of the geological structure of Mesopotamia already held by Persian geologists.

In the more complex conditions of topography and geology obtaining in Britain, the value of the torsion balance for elucidating structure is less certain. That it can be used for detecting exceptional occurrences, e.g., deposits of haematite in limestone, has been proved, but whether it would yield satisfactory results over a structure consisting of Mesozoic rocks overlying unconformably a surface of folded Palaeozoic strata is highly problematical. Effects due to both structures would undoubtedly be present but whether they could be separately evaluated could only be determined, in our opinion, by trial; and, in view of the complex conditions, little reliance could be placed on any determination of depth of the Palaeozoic floor, or on the position of axes of folding in the Palaeozoic strata.

Terrain corrections in this country would also present difficulties. In Persia the alluvium obscuring the structures is very homogeneous

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and terrain corrections can be accurately made. In countries where the surface covering is glacial drift of variable character the corrections, as pointed out by Koenigsberger,[1] can be considered only approximate, whilst the presence of boulders enclosed in the drift below the surface may produce serious disturbances in the gradients due to the structure under investigation.

The balance can certainly be used to detect and approximately delimit shallow structures such as faults and dykes, provided that terrain and topographic corrections can be made with sufficient accuracy, but any attempt to use it to explore structure at depth in complicated districts must meanwhile be regarded as purely experimental.

Appendix

Notes on the theory of the Eötvös Torsion Balance and the Interpretation of the Results

The Eötvös torsion balance consists essentially (Fig. 8) of a weighted beam suspended by a fine wire. At one end of the beam a weight is fixed, from the other end a weight is suspended by a fine wire.

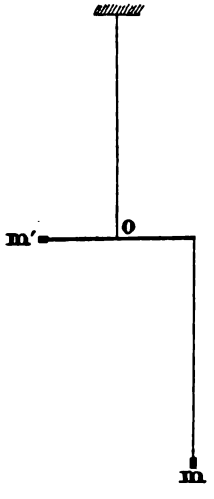

Fig. 8—*The Eötvös Torsion Balance.*

The effect of gravity on the system can be considered in two stages: first, there is an effect due to the horizontal separation of the two weights, and second, there is an effect due to the vertical separation of the two weights.

In considering the first effect we may regard the lower weight as fixed at the end of the beam. At the point of suspension, O, the force of gravity is vertical and the beam is tangential to a level surface. Usually the level surfaces are curved, which means that the forces of gravity on the weights at the ends of the beam are not parallel either to that acting at the centre of the beam or to each other. The diagram, Fig. 9, shows the directions of the forces of gravity at the ends of the beam when the level surfaces are convex upwards. If the level surfaces were concave upwards the arrows denoting direction of gravity would be directed outwards. Only exceptionally will the beam lie so that the forces of gravity are in the vertical plane through the beam and the suspending wire, that is in the plane of the paper in Fig. 9. Usually the direction will be such that there will be a component of gravity in the horizontal plane as shown in Fig. 10. These horizontal components of gravity at the ends of the beam will produce a couple tending to rotate the system. The magnitude of the horizontal components, and therefore of the couple, will depend on the amount of curvature of the level surface. Suppose that, Fig. 11, LL and GG represent the tangents to the level surface through O in the directions of least and greatest curvature of the level surface, which we will assume to be convex upwards. If the beam were lying along LL, as in the upper part of Fig. 12, the horizontal components of gravity acting on weights at the ends of the beam would be less than if it were lying along GG, as in the lower part of Fig. 12. In positions intermediate between LL and GG the horizontal

[1] *Zeitsch. f. prak. Geol.*, 1925, vol. 33, pp. 169–175.

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components have intermediate values and lie on the side of the beam nearest LL. The effect on the beam is a couple tending to turn it into the position LL. LL is called the equilibrium position.

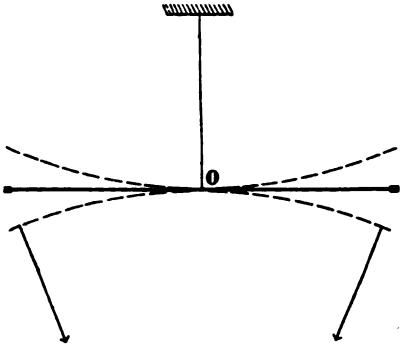

FIG. 9—*The Eötvös Torsion Balance. The effect of the curvature of the level surface.*

If the level surface were concave upwards the horizontal components would be directed outwards from O (dotted arrows in Fig. 11), and there would therefore exist a couple tending to rotate the beam towards GG, that is, GG is the equilibrium position in the case of a level surface concave upwards.

The magnitude of the couple naturally varies with the angle α (Fig. 11), and, further, it is found to be proportional to the difference of the curvatures in the directions GG and LL in whatever position the beam lies with reference to GG and LL. If r_1, r_2 are the radii of curvature of the vertical sections through LL and GG respectively, then the couple tending to turn the beam is equal to $g\left(\frac{1}{r_2}-\frac{1}{r_1}\right)$, and this quantity is called the Horizontal Directing Tendency.

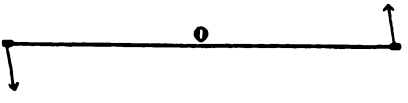

FIG. 10—*The Eötvös Torsion Balance. The effect of the curvature of the level surface.*

The tendency of the beam to swing into one of the principal directions of a fold follows from the above considerations and is illustrated in Fig. 13.

In (a) the continuous line represents the surface of a large homogeneous sphere. The forces of gravity would be everywhere equal and directed towards the centre; there would be no force tending to turn the beam out of any position in which it were set.

If in (a) we take away the material between the continuous line and the convex dotted line (i.e. form a ridge), or replace it by material of less density (i.e. form an anticline with the heavier rocks beneath), there will be a larger proportion of attracting matter at right angles to the plane of the paper

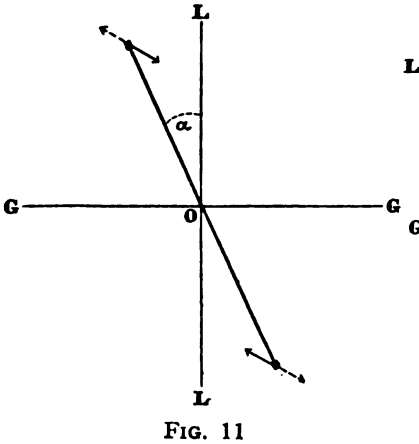

FIG. 11

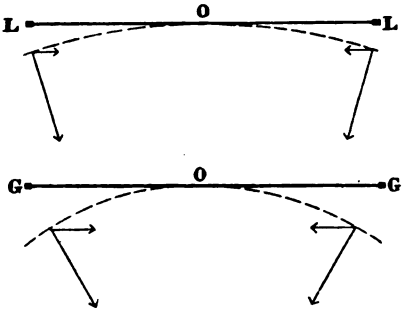

FIG. 12

The Horizontal Directing Tendency.

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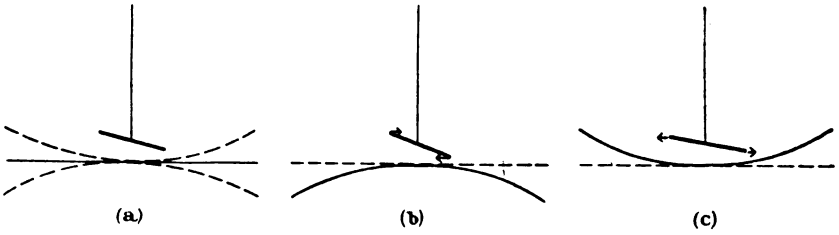

FIG. 13—*The Horizontal Directing Tendency due to folds.*

than in the plane of the paper. The beam will therefore tend to swing into a position at right angles to the plane of the paper, i.e. into parallelism with the axis of the anticline, as shown by the arrows in (b).

Similarly, if we add matter between the continuous line and the concave dotted line a syncline will be formed; the excess of matter is now in the plane of the paper and the beam will therefore tend to swing into a position at right angles to the axis of the syncline, as in (c).

The first stage of our consideration of the effect of gravity on the system therefore shows us that the amount by which the beam will be turned depends on the amount of curvature of the level surface and on the position of the beam with respect to the position of greatest and least curvature of the level surface.

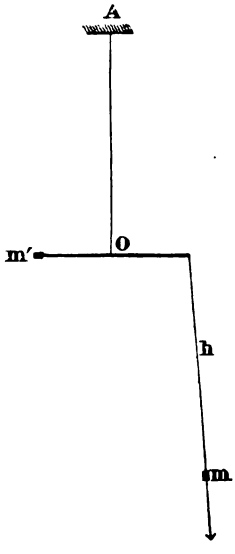

FIG. 14—*The Eötvös Torsion Balance. The Gradient of Gravity.*

There is also an effect on the system because of the vertical distance between the weights. If the mass m (Fig. 14) were at the end of the beam the force of gravity would be acting on it in some direction inclined to the vertical suspending wire OA. We have already considered the effect which would be produced by this inclination. But because these lines of force are continually changing direction as they pass downwards the direction of the force of gravity at the end of the lower suspension will differ from that at the end of the beam. Also the numerical value of gravity will change. This change in direction and magnitude will give rise to a horizontal component the magnitude of which will depend on the distance of m below m'.

Let B (Fig. 15) be a point one centimetre vertically below A. In general, the force of gravity at B will be inclined at a small angle to AB. Suppose that the plane of the paper contains AB and the direction of gravity at B.

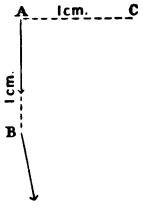

FIG. 15—*The Gradient of Gravity.*

Let C be distant from A one centimetre along the horizontal through A in the plane of the paper. Then it can be shown that the component of the force of gravity at B in the direction AC is equal to the increase in the value of gravity from A to C, which is by definition the gradient of gravity at A (see p. 171). Therefore the horizontal component of the force of gravity on m (Fig. 14) is $m \times h \times$ Gradient.

The gradient at a point has a fixed direction. The beam is set in an arbitrary direction, and therefore the actual value of the turning moment due to the change in magnitude and direction of the force of gravity on the lower weight will depend

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both on the magnitude of the gradient and on its direction relative to the beam.

The second stage of our general analysis of the effect of gravity on the system therefore shows us that the amount by which the beam is turned depends on the magnitude and direction of the gradient.

In summary, the amount by which the beam is turned depends on

(i) the magnitude of the H.D.T.,
(ii) the position of the beam relative to the directions of principal curvature,
(iii) the magnitude of the gradient,
(iv) the direction of the gradient relative to the position of the beam.

By setting the beam in different directions or azimuths we find different values of its deflection. If we set it in sufficient (five[1]) different azimuths the data given by the deflections are sufficient to let us evaluate the four quantities shown above (*see* p. 172).

When these quantities have been calculated from observations made during a survey, there remains from the geological standpoint the important problem of the interpretation of results. Before interpretation is possible it is necessary to know how gradients and H.D.T. values vary over typical structures. In the following pages the effects due to some simple structures are considered.

I. Symmetrical anticlinal fold with horizontal axis; heavy rocks in the core, Fig. 16.

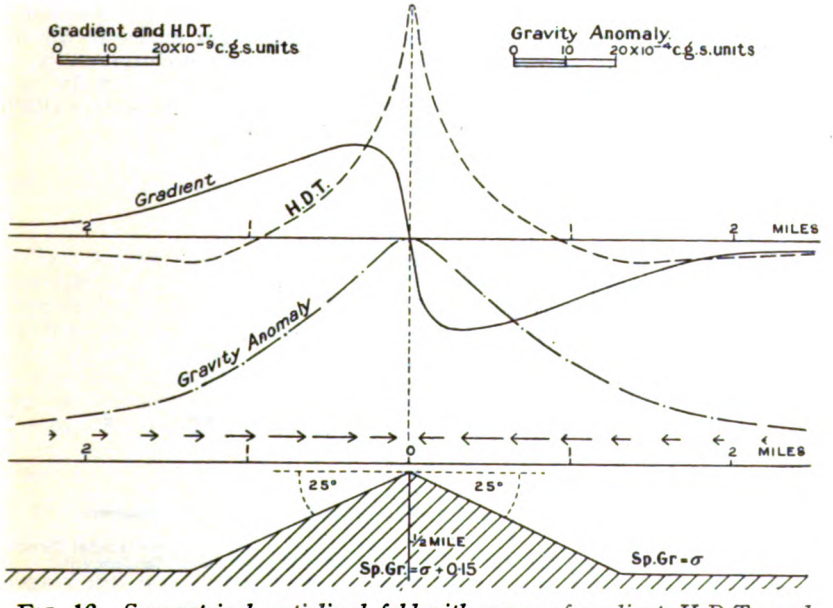

FIG. 16—*Symmetrical anticlinal fold with curves of gradient, H.D.T., and gravity anomaly.*

From general considerations of symmetry, the force of gravity will be greatest immediately above the crest of the fold and will there be perpendicular to the horizontal plane. To the right and left of the fold axis the value of gravity diminishes and its direction becomes inclined to the axial plane of the fold. There is therefore a gradient of gravity and a convex-upward

[1] If the modern double beam balance is used three different azimuth settings are sufficient (see p. 169).

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curvature of the level surfaces. Farther from the fold axis the heavy matter is at greater depth and the directions of the force of gravity become more and more nearly perpendicular to the horizontal plane. Also the value of gravity alters more and more slowly and tends to a constant value. The gradients, therefore, from crest outwards to right or left must first increase and then decrease, and on either side are directed towards the fold axis. Those gradients directed towards the right are shown conventionally in Fig. 16, and in all the figures in this paper, by positive ordinates of the gradient curves: those directed towards the left by negative ordinates. The variation of the gradients is shown in another manner by the line of arrows drawn above the diagram of the structure. The length of each arrow is proportional to the magnitude of the gradient at the position on the surface vertically beneath the tip of the arrow.[1]

An Eötvös balance survey over such a structure would yield values of the gradients in agreement with the length of the arrows in the diagram, and would show them directed as in the diagram towards the axis of the anticline. It would also give the H.D.T. values corresponding to values on the H.D.T. curve of Fig. 16, drawn under the convention that positive ordinates (i) represent the magnitude of the horizontal directing tendency, and (ii) indicate that the equilibrium position of the beam is at right angles to the plane of the paper and parallel to the fold axis. A negative ordinate (i) represents the magnitude of the horizontal directing tendency, and (ii) indicates that the equilibrium position is in the plane of the paper and at right angles to the fold axis. The curve then shows that the maximum H.D.T. occurs at the fold axis and that the beam there tends to turn into parallelism with the axis. It further shows that, for the data given in the figure, about 1¼ miles on either flank away from the axis the beam has a marked tendency to set at right angles to the fold axis, indicating an upward concavity of the level surface corresponding to the concavity of the fold where it flattens out. The gravity anomaly curve shows the difference of the value of gravity at positions on the surface and its shape is clearly comparable with the shape of the structure.

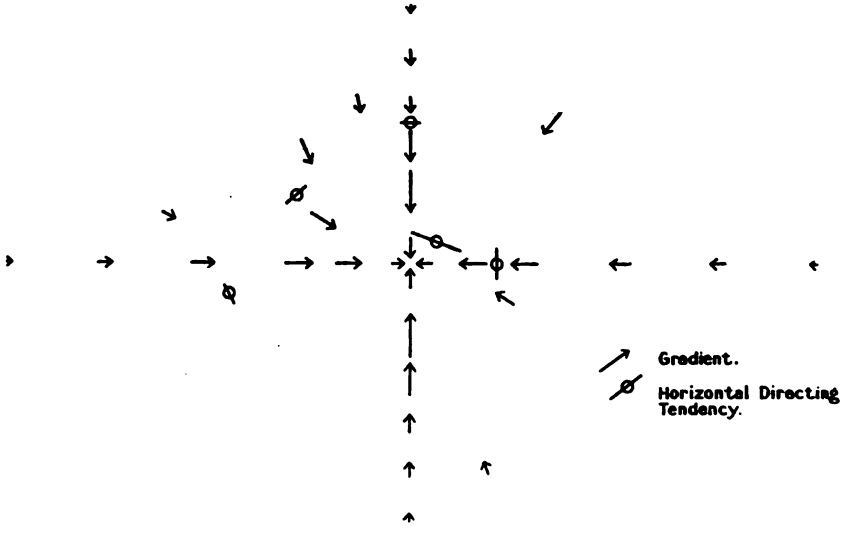

FIG. 17—*Symmetrical dome elongated along one axis. Plan of gradients and H.D.T. values.*

[1] This procedure is followed throughout the following pages. Usually the arrow is drawn *from* the position at which the gradient is to be represented, but this method is not suitable for small scale diagrams.

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II. Symmetrical dome elongated along one axis.

The gradients are shown in magnitude and direction by the arrows in Fig. 17; the magnitude of the H.D.T. and equilibrium position of the beam at the points represented by the centres of the small circles are indicated by the lines drawn through those circles. In this case the H.D.T. lines are parallel to the strike, i.e. they indicate the direction in which the curvature is least.

III. Symmetrical syncline in which the upper rocks are less dense than the lower, Fig. 18.

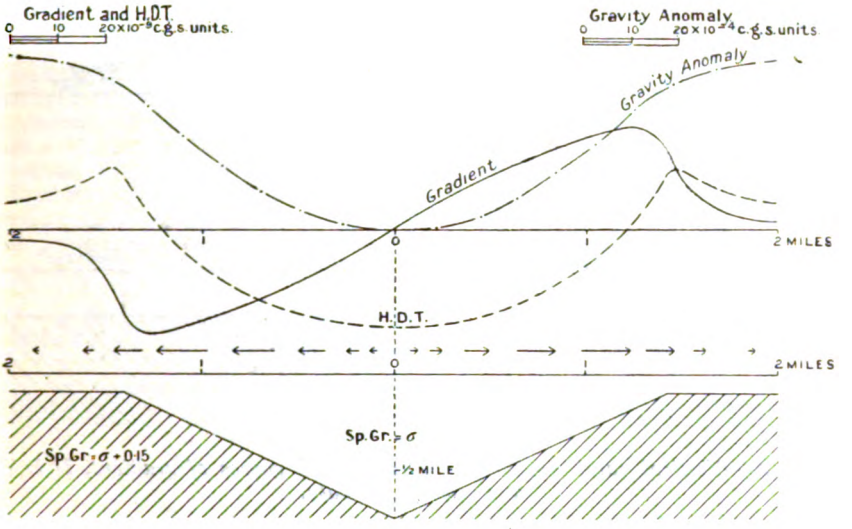

FIG. 18—*Symmetrical synclinal fold with curves of gradient, H.D.T., and gravity anomaly.*

The structure figured in Fig. 18 is a combination of a syncline and two monoclines. The effects due to the three portions of the structure are easily distinguished on the curves. The synclinal part of the structure gives effects which are the reverse of those due to an anticline: the gradients are directed out from the synclinal axis, so that the gradient curve is negative, where for an anticline it would be positive. The negative ordinate of H.D.T. at the fold axis indicates that the equilibrium position of the beam is across the structure instead of parallel to it as in the case of an anticline.

The correspondence of the gravity anomaly curve with the shape of the structure is well marked.

IV. Vertical fault in horizontal strata throwing light rocks down against heavy rocks, Fig. 19.

From left to right the direction of gravity becomes more and more inclined to the right, that is, the level surface (which is always at right angles to the force of gravity) is concave upwards. At the same time the value of gravity increases and its rate of increase becomes greater as the fault is approached. To the right of the fault the value of gravity still increases although its rate of increase diminishes, that is, the gradients become smaller but still remain directed towards the right. The gradient curve of Fig. 19 represents these variations quantitatively. The important fact that the gradients never change direction is shown both by this curve and by the line of arrows. The level surface changes immediately above the fault from a concave-upward surface on the left to a convex-upward surface on the right. Along this axis of inflexion the curvature transverse to the fault is zero, whilst the curvature

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parallel to the fault is also zero (as always in the case of structures extending infinitely in one direction). The H.D.T. is therefore zero immediately above

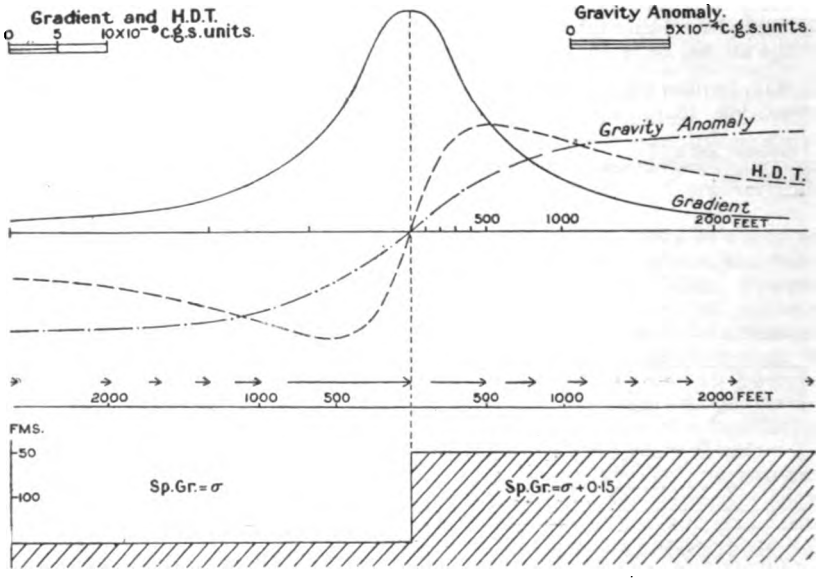

FIG. 19—*Vertical fault in horizontal strata with curves of gradient, H.D.T. and gravity anomaly.*

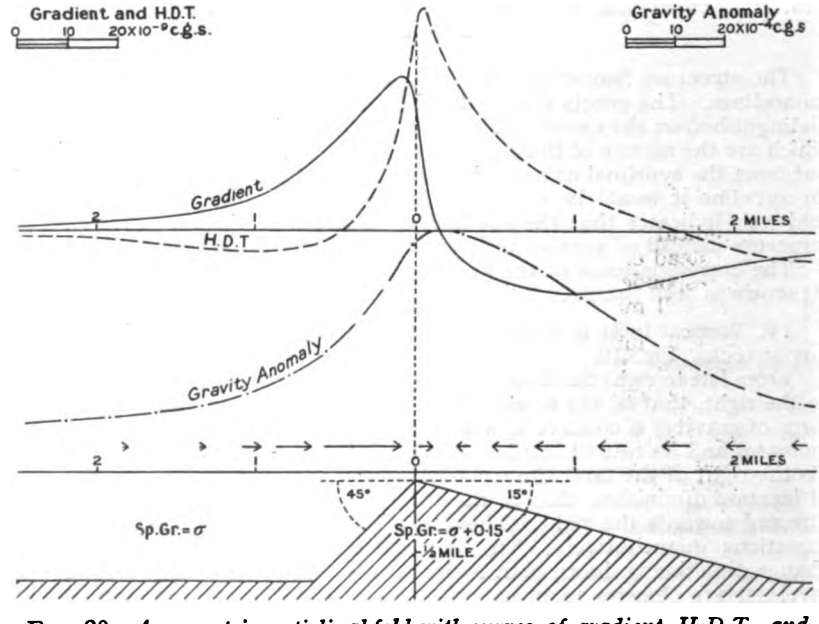

FIG. 20—*Asymmetric anticlinal fold with curves of gradient, H.D.T., and gravity anomaly.*

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the fault. There are two maximum numerical values of H.D.T. where the concave and convex parts of the level surface are most strongly curved. Far to the right and left the value of H.D.T. diminishes again to zero. On the right of the fault, that is, in this case on the upthrow side, the equilibrium position of the beam is parallel to the fault. This is implied in the plotting of the H.D.T. ordinates as positive.

V. Asymmetric anticline with heavy rocks in the core, Fig. 20.

The gradients are directed towards the anticlinal axis but do not become zero immediately above the crest. The position on the surface where the gradient is zero must lie to the right of the crest so that there may be enough heavy matter on the left to counterbalance that on the right. The gradients to the right of this position vary slowly, while to the left they increase and decrease rapidly, very much as in the case of the fault just described. The maximum gradient lies considerably away from the crest towards the steep side of the fold. The general shape of the gravity anomaly curve corresponds with the shape of the structure, but the crest of the curve is a considerable distance to the right of the crest of the surface separating the rocks of different specific gravity (the gravity differential surface).

VI. Vertical dyke of heavy material; for example, dolerite intruding sandstone, Fig. 21.

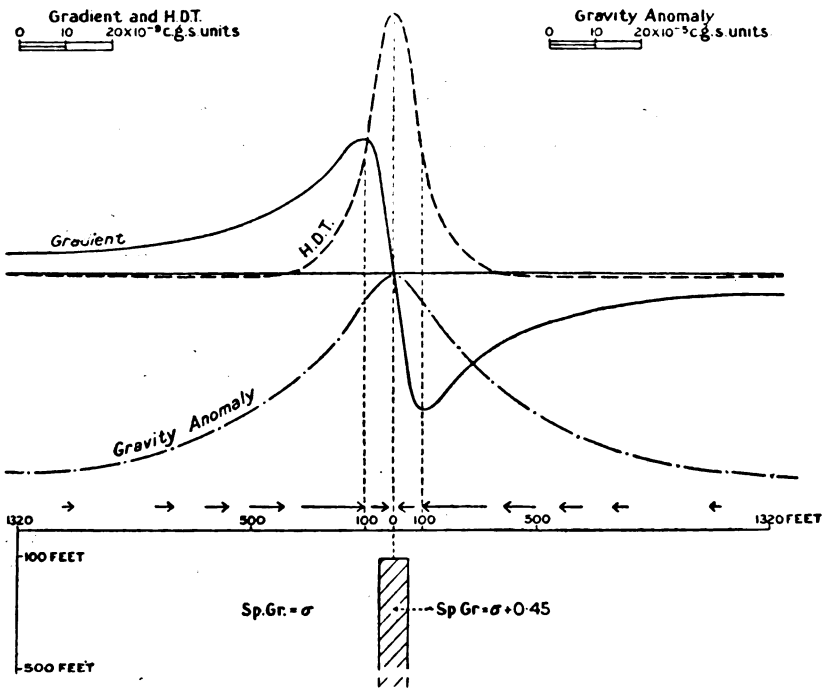

FIG. 21—*Vertical dyke with curves of gradient, H.D.T., and gravity anomaly.*

This case may be considered as a combination of two faults. The maximum numerical gradients occur a short distance beyond the margins of the dyke. The curves showing gravity anomaly, gradient, and H.D.T. are very similar to those for a symmetrical anticline, but are distinguished by the very rapid decrease in magnitude of the various quantities away from the dyke.

VII. If the dyke were thin the gradient curve would be of the same shape as in Fig. 21, but the large gradients would be closer together and the rate

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of decrease of the gradient values would be still more rapid. Unless the stations were very close together only one of the large gradients might be obtained or both might be missed. In the former event a fault might be suspected if the reversal of the small gradients far out was overlooked, or obscured by some other factor. In the other case neither fault nor dyke would be suspected.

VIII. In Fig. 22 (a) is shown the gradient curve due to the presence of a long prism of heavy material situated as shown in the lower part of the figure.

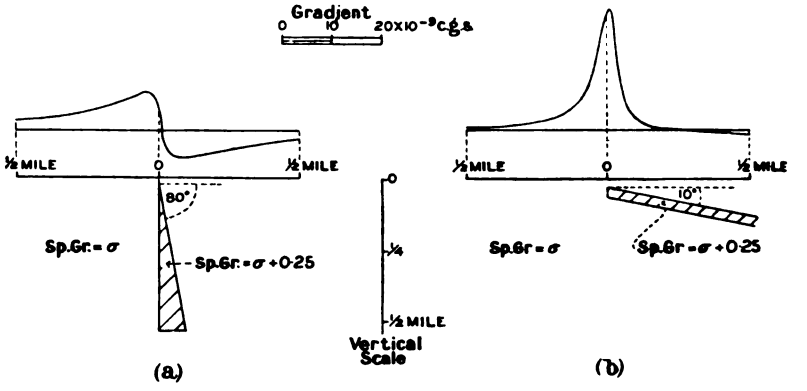

FIG. 22—(a) *Gradient curve due to prism of heavy material.*
(b) *Gradient curve due to sill of heavy material.*

The structure shown in Fig. 22 (b) may be interpreted as a sill stopping abruptly as shown (e.g. faulted), or as an auxiliary structure likely to occur as a ripple on the gently sloping flank of an anticline. These figures are useful for the purpose of modifying the effects due to the theoretical structure assumed in the case of the Ahwaz fold (see Fig. 6).

In conclusion we wish to express our indebtedness to our colleague, Mr. C. H. Dinham, who has carefully read our manuscript, and by valuable suggestions has materially contributed to such clarity as our treatment of the subject possesses.

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A complete bibliography of books and papers dealing with the theory and applications of the torsion balance would run to many pages. We have therefore confined the list below to papers dealing with the geological applications of the balance and with elementary theory and experimental examples. The publications in English most useful to geologists are the papers by Shaw and Jones in the 'Mining Magazine,' and by Fordham in the 'Journal of the Institution of Petroleum Technologists.'

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Department of Scientific and Industrial Research

Summary of Progress

of the

Geological Survey of Great Britain

and the

Museum of Practical Geology

for the Year 1927

PART I

With Report of the
Geological Survey Board and
Report of the Director

LONDON:
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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1927

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Eighth Annual Report on the work of the Survey and Museum.

1. We noted, with interest, the appointment (1st July, 1927) of a Royal Commission on the National Museums and Galleries to report on the legal position, organisation, administration, accommodation, the structural condition of the buildings, and general cost of the institutions containing the National collections situate in London and Edinburgh.

The Director of the Geological Survey and Museum gave evidence before this Commission on the 3rd November, 1927. In view of the primary importance of adequate accommodation in London for the Museum of Practical Geology and the Headquarters of the Survey, we have welcomed with special satisfaction the following answer by the Under-Secretary of State for the Home Department to a question in the House of Commons on the 22nd December, 1927 :—

> "The Royal Commission on the National Museums and Galleries has represented that the present conditions in Jermyn Street are unsatisfactory from every point of view, and that the transfer of the Geological Museum to an appropriate site in South Kensington should be made at the earliest convenient moment. The Chancellor of the Exchequer and my Noble Friend endorse this view, and hope to give effect to it as soon as financial circumstances permit."

We hope that the financial circumstances will allow of progress being made in this urgent matter at an early date.

2. We understand that premises known as Southpark, 19 Grange Terrace, Edinburgh, have been purchased to provide accommodation for the headquarters of the Scottish staff when the lease of the present office of the Survey (33 George Square, Edinburgh) expires in May, 1928. We believe the new premises to be very suitable for the purpose.

Two other changes in the District Offices have been arranged :—

(1) The Manchester Office is shortly to remove from 21 Albion Street to 272 Oxford Road, Manchester, and

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(2) The Whitehaven Office has been closed and the headquarters of the Cumberland unit moved to London.

The Manchester change was necessitated by the expiry of the lease and the Cumberland change was considered opportune as the survey of the coalfields in the district around Whitehaven and Maryport has now been completely revised.

3. The detailed statement of work done by the Survey in 1927, which is given in the Director's Report for the year, shows that the various items of the pre-arranged programme have been carried out. Notwithstanding two vacancies in the grade of 'Geologist' this progress has been coupled with a large amount of attention to the many topics of scientific and economic interest which inevitably emerge in the course of a year.

We are gratified by the smooth working of the arrangements for maintaining a continuous record of additions to information as to the geology of mines.

The ability and zeal of individual members of the staff of the Geological Survey are recognised and appreciated by geologists and others whose work or interest leads to personal contact with them. The alertness and the elasticity of the Survey as a public service may be illustrated by the advance it is making in the methods of presentation of results in its maps and memoirs, and, again, by the scientific enquiry it is conducting on the uses of the Eötvös Balance—experimental investigations bearing on possible aids in geological surveying.

4. The Field Units have been engaged on surveys of eleven districts prescribed by the programme approved for the year, viz. :—

(*a*) London and Southern District (primary six-inch survey).
(*b*) Midlands District (primary six-inch survey).
(*c*) Yorkshire District (revision of six-inch survey).
(*d*) Lancashire District (revision of six-inch survey).
(*e*) Cumberland District (revision of six-inch survey).
(*f*) Northumberland and Durham District (revision of six-inch survey).
(*g*) Ayrshire, Dumbartonshire and Stirlingshire (revision of six-inch survey).
(*h*) Peeblesshire and Midlothian (revision of six-inch survey).
(*i*) Fife and Kinross (revision of six-inch survey).
(*j*) North Highlands (primary six-inch survey).
(*k*) Orkney Islands (primary six-inch survey).

Details of the work carried out by each of the above-mentioned Field Units will be found in the 'Summary of Progress.'

A large amount of revision of the six-inch geological mapping was carried out in the Merthyr Tydfil sheet with a view to the production of a new edition of the memoir on this area. Revised editions of several of the relevant six-inch sheets are now in the press.

5. The Director's Report shows that the total area of ground mapped in 1927 is somewhat smaller than that recorded in some

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previous years. Variations in extent of survey often arise in respect of differences in the geological structures under investigation, or in the extent to which areas had previously been investigated. So far as the 1927 mapping is concerned variations due to such causes may be said to have averaged out. But the very full programmes of field-work carried out during the last two or three years have produced an increased crop of data ripe for publication. Hence it has been found advisable for the Scientific Staff to devote rather less time than usual to the accumulation of new observations and more to the preparation for publication of maps and memoirs on areas recently surveyed. We regard this course as wise ; it aims at the prompt publication and issue of maps and memoirs, and in this and in other ways it expedites the public use of the work of the Survey. As a result of this policy we are gratified to point to the large output of publication work of the Survey during the past year, while we are also glad to call attention to the satisfactory style in which memoirs are being produced and to the improvements now being effected in the production and reproduction of the maps.

A full list of the published matter appears in the Director's Report. In particular, we wish to mention (1) the new London District map, which should be very useful to schools and technical colleges teaching Geology in and around London, (2) the third and much extended edition of the memoir on the ' Oil-Shales of the Lothians '—a technical manual of recognised value, and (3) the annual ' Summary of Progress of the Geological Survey,' which is of increased importance to geological students now that so large a part of the volume is devoted to Appendices on matters of geological interest.

6. We are glad that the Director has found it possible to commence, in accordance with our recommendation of last year, a series of trials with the Eötvös Gravity Torsion Balance on known areas in Britain. The first of these trials was made on the underground extension of the Swynnerton dyke in Staffordshire and the results obtained were in every way satisfactory. A second test is now being carried out on a buried channel filled with Drift deposits in the Kelvin valley area, north-west of Glasgow. This survey has made good progress but was unfinished at the close of the year.

7. Additional memoirs on the water-supply of English counties are in preparation and in the press, and a volume on English Ball Clays has been written which will continue the series of Special Reports on British Mineral Resources.

8. We are pleased to record that Survey co-operation with the soil experts has continued throughout the year. Some practical problems were worked out near Scarborough during September at a joint meeting of soil experts and field geologists. An arrangement for supplying cheap photographic copies of Survey manuscript maps has also been instituted with a view to helping the agriculturists as well as to experiment with a new method of circulating geological information obtained by the Survey.

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A soil map of the Kilmarnock area and a chapter on 'Soils' for the Kilmarnock memoir have been prepared by Professor Berry, and will be published in due course.

9. It is satisfactory to note that under Section 23 of the Mining Industry Act, 1926, to which reference was made in our last year's Report, 108 notifications of proposed borings for minerals have been received up to the 31st December 1927. With a return of the Mining Industry to prosperity it is anticipated that this number will be considerably increased.

10. The programme of field-work for 1928 is :—

(*a*) primary mapping on the six-inch scale in the Midlands district (Shrewsbury sheet), in the south-east of England (Reigate sheet), and in the Orkney Islands ;

(*b*) revision of original six-inch mapping in the following coalfields and the adjacent areas :—Cumberland, Northumberland, Lancashire, Yorkshire, South Wales, Ayrshire, Fifeshire and Renfrewshire ;

(*c*) investigation of underground water supplies ; verification of bore records ; examination of mineral resources ; and application of geophysical methods of surveying.

F. G. OGILVIE,

Chairman.

16*th May*, 1928.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1927

I. REPORT OF THE DIRECTOR

THE activities of the Geological Survey of Great Britain during 1927 were numerous and wide-spread. They may be said to include every part of Great Britain though not of course to an equal degree, as some areas are, from the point of view of economic geology, much more important than others. Enquiries are received daily regarding the geology of the whole country and its application to practical problems, and these are answered by reference to the published maps and memoirs, the great series of manuscript maps preserved at the English and Scottish headquarters, and the mass of accumulated records which have been acquired during a period of nearly a hundred years. But the new work which is done during each field season and prepared for publication during the winter is spread over the whole country so that much fresh information is being obtained from all quarters on a vast range of geological problems.

In the South of England, for example, survey work was carried on in Surrey; a water supply memoir on Sussex is in hand, also new maps and memoirs on Kent; mining records were obtained in Cornwall and Devon; a water supply memoir is printing on Somerset. In the Midlands there are memoirs printing or preparing on Wolverhampton, and Warwickshire water supply, and the Dudley and Shrewsbury Sheets are being revised. The Lancashire and Cheshire coalfields are being most thoroughly re-examined, and in Yorkshire the Huddersfield Sheet is passing through the press and the Glossop Sheet is being re-surveyed. Every development in the great Concealed Coalfield of Yorkshire is being recorded. In East Anglia new maps and memoirs are passing through the press. In Northumberland the coalfield around Alnwick, Morpeth and Newcastle is in hand and a complete re-survey is making progress. A considerable part of the Cheviot Hills was re-mapped. In Cumberland new maps of the important coalfields of Whitehaven and Maryport are being engraved and the Brampton Sheet has been completely revised.

In South Wales a new memoir has appeared on Abergavenny and a second edition of the memoir on the Iron Ores of the Forest of Dean. The Merthyr Tydfil memoir is at present undergoing revision. In North Wales the maps and descriptions of the country around

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Wrexham and Oswestry are approaching completion and publication.

In Scotland work continues in the Ayrshire coalfields and some revision has been made in Renfrewshire, Stirlingshire and Dumbarton. Some Lanarkshire coalfield maps are in the press and new maps are being published of Galloway and Kirkcudbright. A new memoir on Arran is printing. The revision of the coalfield of Fife is in hand and some work has been done in the Midlothian coalfield. The third edition of the 'Oil-Shales of the Lothians' has been published. The new map of the Stonehaven area is at the engraver. Central Sutherlandshire has been visited in order to obtain further information for the completion of the maps. Memoirs are in preparation on Tiree and Ardnamurchan and the primary survey has extended to the Orkneys.

Although during 1927 the activities of the Geological Survey have expanded in several new directions the general scheme of work has of necessity followed very closely those of previous years. On the whole perhaps a less area of ground has been surveyed or revised than usual, but on the other hand the standard and volume of publications have been fully maintained. These two departments to some extent counterbalance one another. It is periodically necessary to shorten field programmes in order to retain the staff for a longer time in the office to complete the proofs of their maps and the manuscripts of their memoirs. This is especially true of coal-field surveys where comparatively little information is to be obtained by an inspection of the surface of the ground, and much depends on a complete study of mine plans, bore records and shaft sections. These must be obtained at the cost of much search from the engineers and others who are in possession of them, and very carefully studied and compared before a knowledge of the underground structure is attained. A glance at the list of six-inch coalfield maps given on pages 12-15 of this report will indicate how much of this class of work has been undertaken during the year. At no period of its history has the Survey been so fully engrossed in coalfield surveys as at present. Every working unit except one is busily engaged in this task. As a relief, however, from the monotony of such work and to provide some of the younger geologists with different problems for investigation, a certain amount of ground, not coal-bearing, has been mapped, such as the Cheviot Hills and parts of Shropshire. In addition to the revision of work done long ago and no longer abreast of economic requirements the six-inch survey of ground not previously mapped was extended to the Orkney Islands, where three geologists of the English staff and one of the Scottish were engaged for three months and mapped a considerable area of comparatively simple ground.

Among the principal developments which indicate an advance in programmes and activities during the past year as compared with previous years the following may be mentioned:

(*a*) The inception of a programme of geophysical work by means

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of the Eötvös balance, which has kept a small party in the field for several months.

(*b*) The establishment of a regular system of registration of all bores and shafts notified under the Mining Industry Act of 1926 (see last year's *Summary of Progress*, pp. 25-28) and the inspection of all important bores. The journals are checked, specimens collected, and a full and accurate record obtained before the work is closed down.

(*c*) A new colour scheme has been devised for the well-known map on the scale of four miles to one inch. It is intended to abandon the old system of colour printing used for this map and to adopt that in which only seven stones are used, as has been done for some time with the one-inch maps of England and Scotland. In consequence it seemed advisable to alter the colour scheme in order to obtain the best results in the simplest possible way by the new process. The objects to be aimed at are (1) simplicity, (2) cheapness, (3) clearness, (4) contrast; and only by very careful consideration of different schemes can these results be obtained. The Index of Colours of the new map is published, and the first sheet of the series is now printing off. This is Sheet 11 (Derby and Sheffield area) which has always been very popular and has commanded a ready sale. Other sheets of this map will follow as the stock in hand is sold out.

(*d*) It is worth while also to mention that the sale of photographic copies of six-inch manuscript maps has been authorised. Only coalfield areas are published on the six-inch scale. Of other areas standard manuscript copies are prepared and deposited in the library for the use of the public who wish to consult them (see pp. 15-16). Hitherto it was only possible to obtain such maps by ordering a hand-drawn and coloured copy, and as these are expensive, costing often 40/- or 50/- each, the sale was very limited. Experiment has proved, however, that photographs from these six-inch maps on the scale of about three inches to one mile may be very useful, though much inferior to hand-coloured copies, and already there is a certain demand for these photographs. It is probable that they will be much appreciated by soil experts who are doing agricultural research work.

Field Work

The programme of field work continued that of 1926. The only new district to be opened out was the Orkney Islands, which were taken in hand on the completion of Caithness and Sutherlandshire in the previous year. The weather during the field season there was very good and rapid progress has been made. With the completion also of the South Ayrshire Sheet (Sheet 14, Scotland) some members of that unit were transferred to the district north and west of Glasgow, where all the coal-bearing strata were revised

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some years ago, but the whole of the one-inch map (Sheet 30, Scotland) has not yet been re-examined.

In the London district much work has been done in preparing new editions of some very popular maps such as Dover, Margate, Hastings and Dungeness, all of which have been sent to the engraver. The Aldershot Sheet is also engraving, and the Moreton-in-the-Marsh Sheet will soon follow. In East Anglia the Ipswich Sheet (207) has been published and Sudbury (206), Woodbridge (208) and Felixstowe (225) are at the engraver. In writing up the memoirs on these sheets the assistance of Professor Boswell and Mr. Osborne White has been obtained. Only the Aldershot Sheet, which is a very important one in many respects, has been completely re-surveyed on the six-inch scale. The others have obtained such revision as seemed absolutely necessary and could be given to them in the time available.

In the West Midlands the unit working under Mr. Cantrill has been engaged in six-inch mapping of the Shrewsbury area for the first time. That coalfield is comparatively unimportant, but the surrounding district is rich and varied in its geological features and is classic ground for the student of the older Palaeozoic and pre-Cambrian rocks of England. This staff unit has had an exceptionally large amount of publications passing through the press. Mention must also be made of the work of Dr. Robertson in South Wales. Accompanied for a time by Mr. John Pringle and Dr. Crookall he has examined a large part of the Merthyr Tydfil Sheet (231) in preparation for a new edition of the memoir on it which has been out of print for a number of years. As in the Abergavenny area, which he examined last year, it is probable that some of the current six-inch coalfield sheets will be issued in a revised form.

The Lancashire and Yorkshire units have lent certain members of their staffs for part of the year to engage in the primary survey of the Orkney Islands. The former is engaged principally in the difficult work of bringing out a new edition of the Manchester Sheet, a district of considerable complexity and obscurity. The Wigan Sheet (84) has been taken in hand. The Yorkshire unit is similarly engaged on the Huddersfield Sheet, of which a manuscript copy was exhibited in September when the British Association met in Leeds. The map is now engraving and the memoir is being written. Field work in Yorkshire was confined to the Glossop Sheet (86) which is about half finished.

In Northumberland and Durham field work was carried out both in the coalfield in the neighbourhood of Morpeth and in the volcanic rocks of the Cheviot Hills. That field unit has now a considerable area surveyed and not yet ready for publication: consequently field work in the coming season may be considerably reduced.

In Cumberland a notable stage of progress was attained by the completion of two very difficult and important sheets, Whitehaven (28) and Maryport (22) and also of the Brampton Sheet (18) which is principally Carboniferous Limestone with some coal seams. As

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this unit has now finished the very puzzling Whitehaven coalfield, which had not previously been well understood, and as its operations in future will be at some distance from Whitehaven, which is not a very convenient centre, the staff was shifted to London at the end of the year and the Whitehaven office was closed.

In Scotland field work was comparatively small as the slow progress of publication of coalfield maps and memoirs greatly restricted the time available for examining new areas in the field. All the important coalfields of Scotland have now been revised and most of the new six-inch maps are published. Fifeshire and South Ayrshire are the principal districts under investigation at present, with the less important coalfields of Douglas and Muirkirk. Dr. Read made a rapid inspection of parts of Sutherlandshire which had been mapped long ago and now require to be dry-proofed for engraving. Dr. Campbell of Edinburgh University has also furnished a revised one-inch map of the Stonehaven area (Sheet 67), based on a personal examination of all the outcrops. This map is engraving and will soon be published.

In connection with the field work in the various districts the members of the headquarters staff have also displayed great activity. Mr. Pringle, Mr. Chatwin and Dr. Crookall have paid many visits to the field with the object of directing the fossil collectors and securing palaeontological and palaeobotanical specimens and information to complete and illustrate the work of the field geologists. The task of bore examination has been mostly in the hands of Mr. Templeman in England and Mr. Manson in Scotland. Mr. John Rhodes has taken several hundred photographs of typical geological subjects and thirty-four have been taken by Mr. Manson. Mr. Eckford, Mr. Tait and Mr. Strachan have collected specimens for the geologists in Scotland and in Northumberland. The staff of assistants has been increased by the addition of three officers (two Technical Assistants and one General Assistant)—one in Scotland and two in England—and the new recruits have been undergoing training under experienced supervision in the manifold duties they will be called upon to perform.

Publications

The list of publications is exceptionally long and includes the following items :—

English

1 quarter-inch Index, 7 one-inch maps (2 solid and 5 drift), 54 six-inch maps (solid and drift editions of each).

Scottish

4 one-inch maps, 15 six-inch maps (solid and drift editions of each), and 4 Vertical Sections.

Most of these items were in the press at the close of 1926 and the

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work done on them during the year has been principally the correction of engraved proofs and of coloured standards.

Several items in this list are worthy of special mention.

The new quarter-inch Index is the first part of a third edition of the quarter-inch map. The first geological Sheet is in the press and almost ready for issue at the close of the year.

The London District map is in several ways a new departure. It is the largest colour-printed map yet issued by the Geological Survey of Great Britain, measuring 28 in. by 36½ in. and representing an area of 779 square miles. The topographical basis is the excellent one-inch Tourist Map of the Ordnance Survey, which is more thoroughly up-to-date than the maps used in producing our one-inch Sheets of South London (270), North London (256), Beaconsfield (255), Windsor (269), Romford (257), and Dartford (271). The new map contains parts of the six sheets above enumerated but was not printed from their plates as an entirely new series of stones was prepared in order to secure complete uniformity throughout. An interesting feature of this map is the representation of rivers, ponds and reservoirs in blue, as on the ordinary topographical sheets. This gives distinctness to the river-systems and in no way interferes with the usefulness of the map to the geologist. As the London area had previously been represented on four one-inch sheets it is believed that this new map will prove much more convenient to the public and should be especially useful to schools and technical colleges in and around London. Its production was an experiment made to ascertain if the colour-printing process now in vogue for our maps would produce a large and complex sheet in a satisfactory manner, and the general verdict of the public has been that the map is very successful. It is expected that for the use of Londoners interested in geology this will replace all other maps.

Another map that has several new features is the Rochdale map (Sheet 76). Hitherto it has been usual to produce maps of coalfield areas in two editions, 'Solid' and 'Drift.' Where only the 'drift' edition was issued complaints were received that the coalfields were often entirely covered with boulder-clay or gravel and consequently were very inconspicuous. Hence a solid edition was wanted for the use of mining students and mining engineers. In most cases the same engraved plate showing topography and geological lines was used for both editions. In this Rochdale map, however, two engraved geological plates are used. The topographical basis is the same in both, but in the 'solid' plate the drift boundaries are omitted, while in the 'drift' plate many of the outcrops of coal seams and other 'solid' details are not shown. Each map, in fact, is designed for a special purpose. The 'solid' shows all possible detail of the underlying rocks. The 'drift' displays especially the nature and distribution of the superficial deposits. It is believed that in this way a better result is obtained at a trifling extra cost, and the 'drift' map produced is more satisfactory for the geographer and agriculturist, while the mining engineer also obtains

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a map specially adapted for his use. In the difficult matter of map production finality is never reached, but as an experiment the Rochdale Sheet has proved a success and it is probable that future one-inch coalfield maps will follow this model more or less closely. We have in the press a Scottish map (Kilmarnock, Sheet 22) which in some respects is more complete than the Rochdale map; but till the final proofs are passed and copies come from the press it is not possible to pass judgment on it.

The six-inch maps published during the year are exceptionally numerous, and by examining the list it will be seen that many coalfields are receiving attention. These maps are now more nearly reduced to standard form. They usually have measured vertical sections on their margins; and by the thorough use of index letters it is quite possible to represent the whole geology without the use of colour. As a matter of fact students in the universities are now being taught to read these plain or uncoloured maps quite efficiently, and coloured copies are required only for certain special purposes. The sale of plain maps increases yearly, while the sale of hand-coloured copies is continually shrinking.

The six-inch maps of South Wales, revised by Dr. Robertson, are the second editions of maps originally made by Sir Aubrey Strahan and Dr. Gibson, with additional details and corrections to bring them up to date. In Northumberland a new set of topographical six-inch maps has recently been issued by the Ordnance Survey and those sheets in our list which bear the index letter N are on the new topography. The new series does not correspond exactly in numbers or in boundaries with the series which it replaces, and in some cases most of the geology has been transferred from an old series map with little modification, but new indexes and vertical sections are frequently necessary.

Of the four Scottish one-inch maps published during the year two are colour-printed versions of the map originally issued some years ago. The Kirkcudbright map, Sheet 5, has the revision of the Silurian rocks made by Dr. Peach and Dr. Horne; the igneous rocks have been re-named by Dr. Read, and the drift is represented by stipple. The Coll map completes the publication of Mull in colour-printed form.

Both in England and in Scotland a large number of six-inch maps have been prepared in standard form and deposited in the library for reference by the public (pp. 15-16).

The memoirs issued during 1927 were mostly descriptions of new colour-printed one-inch Sheets. The Abergavenny memoir, however, is not accompanied by a new map as that Sheet is neither superseded nor sold out, while the memoir has for some time been out of print, and we have had many enquiries about a new edition. Perhaps the most interesting volume of the year is the third edition of the 'Oil-Shales of the Lothians.' This work is well known as the standard authority on the subject of which it treats. Two new contributors have made their appearance in this edition, Mr. Conacher and Mr.

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E. M. Bailey, both of whom have spent a life time in the Scottish shale-oil industry and are recognized authorities on the subjects they handle in the memoir. This work has been very favourably reviewed by the technical press. The memoir on the South Staffordshire coalfield, by Mr. Whitehead and Mr. Eastwood, fills a recognised gap in our descriptive literature of British coalfields. It follows after 60 years the second edition of the standard work by J. Beete Jukes, which has always been regarded as one of the best and most original monographs on a British coalfield. Unfortunately the coals of this district have been to a large extent worked out, but the history and geological details of the field have received very full attention in the new memoir now published. The Rossendale memoir (Sheet 76) marks the beginning of publication of the revision of the Lancashire coalfield.

The following maps and memoirs were published during 1927 :—

I.—Maps

English and Welsh maps published in 1927

¼ inch to 1 mile:—

Index to Colours and Symbols. *Revised Edition.*

1 inch to 1 mile :—

London District (*Drift Edition*).

Sheet 76.—Rochdale (*Solid and Drift Editions*). By R. L. Sherlock, D. A. Wray, W. Lloyd, L. H. Tonks and W. B. Wright, District Geologist.

Sheet 121.—Wrexham (*Solid and Drift Editions*). By C. B. Wedd, H. H. Thomas, D. A. MacAlister, B. Smith, L. J. Wills and W. B. R. King ; G. W. Lamplugh, District Geologist.

Sheet 139.—Stafford (*Drift Edition*). By E. E. L. Dixon, R. W. Pocock, T. H. Whitehead, T. Robertson and W. Gibson and T. C. Cantrill, District Geologists.

Sheet 207.—Ipswich (*Drift Edition*). By F. J. Bennett, J. H. Blake, W. H. Dalton and W. Whitaker. Transferred to New Series map with minor corrections.

6 inches to 1 mile (coalfield maps) :—

Brecknockshire, 47 N.W. (Mon. 11 N.W.)—Beaufort (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Brecknockshire, 47 N.E. (Mon. 11 N.E.)—Brynmawr (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Brecknockshire, 48 N.W. (Mon. 12 N.W.)—Pwll-du (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Cumberland, 18 N.E.—Nether Denton. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 19 S.W.—Midgeholme. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 25 N.E.—Cold Fell. Original survey by E. J. Hebert. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 53 N.E.—Seaton. Original survey by R. Russell. Revised by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 67 S.E.—Cleator Moor (*Revised Edition*). Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by B. Smith, District Geologist.

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Cumberland, 68 N.W.—Arlecdon. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon ; B. Smith, District Geologist.

Durham, 6 N.W.—Whickham. Original survey by H. H. Howell. Revised by W. Anderson and G. A. Burnett ; R. G. Carruthers, District Geologist.

Durham, 6 N.E.—Gateshead. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Durham, 6 S.W.—Burnopfield. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Durham, 6 S.E.—Kibblesworth. Original survey by H. H. Howell. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

Glamorganshire, 6 S.E. (Mon. 10 S.E.)—Twyn-carno (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 12 S.E.—Blaenllwynau (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 13 N.W. (Mon. 17 N.W.)—Bedwellty Pits (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Glamorganshire, 13 S.W. (Mon. 17 S.W.)—Cwm-syfiog (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 11 S.W.—Tredegar (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 11 S.E.—Aberystruth (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 12 S.W.—Blaenavon (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Monmouthshire, 18 N.W.—Varteg (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Monmouthshire, 18 S.W.—Abersychan (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

[1]Northumberland, 26 S.W.—Eglingham. Original survey by W. Topley, Revised by G. A. Burnett ; R. G. Carruthers, District Geologist.

[1]Northumberland, 32 S.E.—Lesbury. Original survey by W. Topley. Revised by R. G. Carruthers, District Geologist.

[1]Northumberland, 37 N.E.—Callaly. Original survey by W. Topley. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

[1]Northumberland, 38 N.W.—Edlingham. Original survey by W. Topley. Revised by W. Anderson ; R. G. Carruthers, District Geologist.

[1]Northumberland, 45 N.W.—Framlington Gate. Original survey by W. Topley. Revised by A Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 45 S.E.—Weldon. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 47 N.W.—Hauxley. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 47 S.W.—Hadstone Carrs. Original survey by W. Topley. Revised by A. Fowler ; R. G. Carruthers, District Geologist.

[1]Northumberland, 54 N.E.—Linden. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 6 N.E.—Felkington. Original survey by W. Gunn. Revised by R. G. Carruthers and A. Fowler ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 6 S.E.—Duddo. Original survey by W. Gunn. Revised by R. G. Carruthers and F. Marsden ; R. G. Carruthers, District Geologist.

[2]Northumberland, N. 50 N.W.—Pauperhaugh. Original survey by W. Topley. Revised by A. Fowler and J. Maden ; R. G. Carruthers, District Geologist.

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[1]Correspond to Topographical Sheets issued by Ordnance Survey 1894-1897.
[2]Correspond to Topographical Sheets on new meridian revised by Ordnance Survey 1912-1922.

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[1]Northumberland, N. 50 S.W.—Wingate. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

[1]Northumberland, N. 50 S.E.—Viewlaw. Original survey by W. Topley. Revised by J. Maden ; R. G. Carruthers, District Geologist.

Staffordshire, 71 S.W. (Worcs. 4 S.W.)—Stourbridge. Surveyed by T. H. Whitehead ; T. C. Cantrill, District Geologist.

Yorkshire, 216 N.W.—Thornton. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 216 S.W.—Queensbury. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 216 S.E.—North Bierley. Original survey by J. C. Ward, J. Lucas, C. Fox-Strangways and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 N.W.—Pudsey. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 N.E.—Armley and Bramley. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 217 S.W.—Tong. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by J. V. Stephens ; C. N. Bromehead, District Geologist.

Yorkshire, 217 S.E.—Gildersome. Original survey by J. C. Ward, J. Lucas and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 231 N.E.—Wyke. Original survey by J. C. Ward and R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 N.W.—Birkenshaw. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 N.E.—Morley. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 232 S.W.—Liversedge. Original survey by R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 232 S.E.—Batley. Original survey by R. Russell. Re-surveyed by Wilfrid Edwards ; C. N. Bromehead, District Geologist.

Yorkshire, 245 N.E.—Barkisland. Original survey by J. R. Dakyns. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Yorkshire, 246 N.W.—Elland. Original survey by J. R. Dakyns, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead. District Geologist.

Yorkshire, 246 N.E.—Rastrick. Original survey by J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 246 S.W.—Golcar. Original survey by J. R. Dakyns, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Yorkshire, 247 S.W.—Kirkheaton. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray ; C. N. Bromehead, District Geologist.

Scottish maps published in 1927

1 inch to 1 mile :—

Sheet 5.—Kirkcudbright. Revised by B. N. Peach and J. Horne.

[1]Correspond to Topographical Sheets on new meridian revised by Ordnance Survey 1912-1922.

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Mining information by G. V. Wilson. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 19.—Bowmore. By S. B. Wilkinson and B. N. Peach. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 27.—Portaskaig. By B. N. Peach, S. B. Wilkinson and C. T. Clough. (*Colour-printed edition, replacing hand-coloured edition*).

Sheet 51.—Coll. By E. B. Bailey, J. E. Richey, G. V. Wilson, G. A. Burnett, V. A. Eyles and J. B. Simpson; E. B. Bailey, District Geologist.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 24 S.E.—Weitshaw Muir. Original survey by J. Geikie. Revised by A. G. MacGregor; E. B. Bailey, District Geologist.

Ayrshire, 26 S. W.—Ponesk Burn. Original survey by B. N. Peach. Revised by G. V. Wilson; M. Macgregor, District Geologist.

Ayrshire, 29 N.E.—Sorn, North of. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 29 S.E.—Darnconner. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 30 S. W.—Aird's Moss. Original survey by B. N. Peach. Revised by E. M. Anderson and J. B. Simpson; E. B. Bailey and J. E. Richey, District Geologists.

Ayrshire, 35 S.E.—Glaisnock. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 40 N.E.—Polquhairn. Original survey by J. Geikie. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Ayrshire, 41 S.W.—Craigman. Original survey by J. Geikie and B. N. Peach. Revised by J. B. Simpson; E. B. Bailey, District Geologist.

Fifeshire, 39 N.E.—Fordell. Original survey by A. Geikie. Revised by J. K. Allan; C. H. Dinham, District Geologist.

Lanarkshire, 16 S.E.—Jackton. Original survey by J. Geikie. Revised by R. G. Carruthers, C. H. Dinham and J. E. Richey; L. W. Hinxman and E. B. Bailey, District Geologists.

Lanarkshire, 31 S.E.—Auchlochan. Original survey by B. N. Peach. Revised by L. W. Hinxman and G. Ross; M. Macgregor, District Geologist.

Lanarkshire, 37 N. E.—Coalburn. Original survey by B. N. Peach. Revised by C. B. Crampton and G. Ross; M. Macgregor, District Geologist.

Stirlingshire, 17 N.E.—Stirling, St. Ninians. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read; C. H. Dinham, District Geologist.

Stirlingshire, 18 N.W.—Fallin. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read; C. H. Dinham, District Geologist.

Stirlingshire, 23 N.E.—West Plean. Original survey by B. N. Peach. Revised by C. B. Crampton and C. H. Dinham; L. W. Hinxman and C. H. Dinham, District Geologists.

Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. These maps are not to be published. The English maps are deposited in the head office in London. The Scottish maps are deposited in the Edinburgh office.

English manuscript maps deposited for reference

Berkshire, 49 N.E. (Hants. 12 N.E.) (part); 50 N.W. (Hants. 13 N.W.) (part).
Cumberland, 54 S.E.

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Essex, 6 S.W. (Suffolk 72 S.W.) (part), S.E. (Suffolk 72 S.E.); 12 N.W. (Suffolk 79 N.W.), N.E. (Suffolk 79 N.E.).
Hampshire, 12 S.E. (part); 13 S.W.; 20 N.E. (part); 21 N.W. (part).
Shropshire, 16 S.E.; 23 N.E. (and 24 N.W.), 23 S.E.; 30 N.E., S.E.; 31 N.W., S.W.
Staffordshire, 22 S.W., S.E.; 23 S.W., S.E.; 24 S.W., S.E.; 25 S.W. (part); 28 N.W., N.E., S.E.; 29 N.W., N.E., S.W., S.E.; 30 N.W., N.E., S.W., S.E.; 31 N.W. (part), S.W. (part); 35 N.E., S.E.; 36 N.W., N.E., S.W., S.E.; 37 N.W., N.E., S.W., S.E.; 38 N.W. (part), S.W. (part); 43 N.W., N.E., S.W., S.E.; 44 N.W., N.E., S.W., S.E.
Surrey, 15 (N.W. and N.E.), S.E.; 16 N.W., N.E., S.W., S.E.; 17 S.W., S.E.; 18 S.W. (part); 22 N.E., S.W., S.E.; 23 N.W., N.E., S.W., S.E.; 24 N.W., N.E., S.W., S.E.; 25 N.W.; 30 N.W., N.E., S.W., S.E.; 31 N.W., N.E., S.W., S.E.; 32 N.W., N.E., S.W., S.E.; 37 N.W. (part), N.E. (part); 38 N.W. (part), N.E. (part); 39 N.W. (part), N.E. (part).
Sussex, 2 S.W., S.E.; 10 N.W., S.W.; 12 N.W. (part), N.E. (part); 13 N.W. (part), N.E. (part); 20 N.E., S.E.; 21 N.W., S.W., S.E.; 22 S.W. (part), S.E. (part); 23 S.W. (part), S.E.; 33 N.E., S.E.; 34 N.W., N.E., S.W., S.E.; 35 N.W., N.E., S.W., S.E.; 36 N.W., N.E., S.W., S.E.; 47 N.W., N.E., S.E., ; 48 N.W., N.E., S.W., S.E.; 49 N.W., N.E., S.W., S.E.; 60 N.E., S.E.; 61 N.W., N.E., S.W., S.E.; 62 N.W., N.E., S.W., S.E.; 63 N.W., N.E., S.W., S.E.; 68 N.W. (part), S.W. (part), S.E. (part); 72 N.W., N.E., S.E.; 73 N.W., N.E., S.W., S.E.; 78 N.W., N.E., S.E.; 79 N.W., N.E., S.W., S.E.; 80 N.W., N.E., S.W.; 81 N.W., N.E.; 82 N.E.; 83 N.W.
Worcestershire, 39 S.E. (part); 46 N.E. (part).
Yorkshire, 259 N.E.; 260 N.W.

Scottish manuscript maps deposited for reference

Argyllshire, 51; 63 (and 64); 65 (and 79); 70 S.W., S.E.; 78; 95; 97; 104 N.W., N.E., S.E.; 109 N.W., S.E.; 116.
Ayrshire, 19 N.E., S.E.; 32 S.E.; 33 S.W.; 39 N.E.; 51 S.E.; 52 S.W., S.E.; 53 N.W.; 57 N.E.; 58 N.W.
Berwickshire, 13; 19.
Caithness-shire, 26a N.E., S.E.; 31a N.E., S.E.
Edinburghshire, 20 N.W., S.W.; 23; 25.
Haddingtonshire, 22 N.W., S.W.
Lanarkshire, 22 N.E., S.E.; 26 S.E.; 29 N.E., S.E.; 31 N.W., S.W.; 37 N.W.
Roxburghshire, 1 S.W., S.E.; 2 S.W.; 3; 4 N.W., S.W.; 7 N.E., S.E.; 8; 13 N.E., S.W., S.E.; 14; 18 N.E., S.E.; 19; 20.
Selkirkshire, 1 S.W.; 3; 4 S.W.; 7.
Sutherland, 33; 34; 35; 42; 43; 44; 52; 53; 54; 62; 63; 64; 75.

List of maps in the press at the close of 1927

English maps in the press

inch to 1 mile:—

Sheet 11.—Derby, Lincoln, Sheffield, Stafford (*Solid Edition*). *Reprinting.*

1 inch to 1 mile:—

Sheet 77.—Huddersfield (*Drift Edition*).
Sheet 137.—Oswestry (*Solid and Drift Editions*).
Sheet 153.—Wolverhampton (*Solid and Drift Editions*).
Sheet 206.—Sudbury (*Drift Edition*).
Sheet 208.—Woodbridge (*Drift Edition*).
Sheet 225.—Felixstowe (*Drift Edition*).
Sheet 274.—Ramsgate (*Drift Edition*).

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Sheet 285.—Aldershot (*Drift Edition*).
Sheet 290.—Dover (*Drift Edition*).
Sheet 320.—Hastings (*Drift Edition*).
Sheet 321.—Dungeness (*Drift Edition*).

6 Inches to 1 mile (coalfield maps) :—

Cumberland, 19 N.W. ; 53 N.E. ; 54 N.W., S.W. ; 62 N.W., S.W. ; 72 N.E.
Glamorganshire (*Revised Edition*), 12 N.E. (Mon. 16 N.E.).
Lancashire, 87 N.W., N.E., S.W. ; 88 N.W., N.E., S.E. ; 95 N.W.
Monmouthshire (*Revised Editions*), 17 N.E., S.E. ; 18 S.E.
Northumberland, N. 10 N.E. ; N. 11 N.W. ; N. 35 S.E. ; N. 43 N.W., S.E. ; N. 49 S.E.
Shropshire, 12 N.W., N.E., S.W., S.E. ; 18 N.E. ; 19 N.W., S.W.
Yorkshire, 215 N.E., S.E. ; 246 S.E. ; 247 N.W., N.E. ; 260 N.E. ; 261 N.W.

Scottish maps in the press

1 inch to 1 mile :—
Sheet 22.—Kilmarnock (*Solid and Drift Editions*).
Sheet 23.—Hamilton (*Solid Edition*).
Sheet 32.—Edinburgh (*Drift Edition*).
Sheet 67.—Stonehaven.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 26 S.E. ; 30 N.E. ; 31 N.W. ; 34 S.W. ; 40 N.W., S.W., S.E. ; 41 N.W. ; 46 N.W., N.E., S.E. ; 47 N.W. ; 50 N.E., S.E.
Clackmannanshire, 139 N.W., S.E.
Fifeshire, 34 S.E. ; 37 N.W. ; 40 N.E. (and 41 N.W.)
Fifeshire and Kinross-shire, 34 N.E.
Lanarkshire, 19 N.W. ; 32 S.W., S.E.
Stirlingshire, 10 S.E. ; 18 S.W., S.E.

II.—Vertical Sections of Strata

In addition to the maps enumerated above four large sheets of vertical sections of the strata of the Central Coalfield of Scotland, mostly drawn from details of borings and shafts, on the scale of one inch to 40 feet, have been published. These serve to illustrate the series of Economic Memoirs on the Central Coalfield of Scotland and the six-inch published maps of that coalfield. Each sheet contains from ten to twenty vertical sections. Another sheet illustrating this coalfield is in the press and four sheets of vertical sections illustrating the South Wales Coalfield are being reprinted.

Scottish Vertical Sections published in 1927

Sheet 19.—Vertical Sections illustrating the Central Coalfield. Coal Measures in Areas IX, VI, and south part of VII. Hamilton, Dalserf, Wishaw, Shotts, Fauldhouse, and Armadale Districts.
Sheet 12.—Vertical Sections illustrating the Central Coalfield. Coal Measures showing strata below Splint Coal in Area VII. Rutherglen, Motherwell, and Holytown Districts.
Sheet 13.—Vertical Sections illustrating the Central Coalfield. Millstone Grit and Upper Limestone Group, along south and east borders. Areas IV, IX, VI and II.

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Sheet 15.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series, along south and east borders. Areas IX, VI and II.

English Vertical Sections in the press at the close of 1927

Sheet 81.—Sections of Shafts in the Steam Coal Series in the 1-inch map Sheet 232 (parts of Monmouthshire and Glamorganshire). Scale 100 feet to an inch. *Reprinting.*

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. *Reprinting.*

Sheet 84.—Sections of Shafts below the Pennant Grit in the Rhondda Fawr and in the Upper Measures at Llantwit. Scale 100 feet to an inch. *Reprinting.*

Sheet 85.—Sections of Shafts, &c., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. *Reprinting.*

Scottish Vertical Sections in the press at the close of 1927

Sheet 14.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series in Areas IV and VIII. Paisley, Giffnock, and East Kilbride.

III.—Memoirs

The following list shows the memoirs published during the year 1927. The work done on them has been mainly the correction of proofs and preparation of indexes.

English Memoirs published in 1927

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the Year 1926. 202 pp.; 6 plates; 42 text-figures. 1927. Price 4*s.* 6*d. net.*

Special Reports on the Mineral Resources of Great Britain: Vol. X. Iron Ores—The Haematites of the Forest of Dean and South Wales. By T. Franklin Sibly, D.Sc. *Second Edition.* Revised by W. Lloyd, B.Sc. 101 pp.; 17 text-figures. 1927. Price 2*s. net.*

The Geology of the Southern Part of the South Staffordshire Coalfield (South of the Bentley Faults). By Talbot H. Whitehead, M.Sc., A.R.C.Sc., and T. Eastwood, A.R.C.Sc. With contributions by T. Robertson, B.Sc., Ph.D., A.Inst.M.M. 218 pp.; 13 plates; 5 text-figures. 1927. Price 6*s.* 6*d. net.*

The Geology of the South Wales Coalfield. Part II. Abergavenny. (Explanation of one-inch Sheet 232: England and Wales). By Aubrey Strahan, M.A., F.G.S., and Walcot Gibson, F.G.S. With notes by J. R. Dakyns, M.A., and Prof. W. W. Watts, M.A. *Second Edition* by T. Robertson, B.Sc., Ph.D., A.Inst.M.M. 145 pp.; 4 plates; 20 text-figures. 1927. Price 3*s.* 6*d. net.*

The Geology of Belford, Holy Island, and the Farne Islands. (Explanation of one-inch Sheet 4: England and Wales). By W. Gunn. *Second Edition* by R. G. Carruthers, C. H. Dinham, B.A., G. A. Burnett, B.Sc., and J. Maden, M.Sc. 195 pp.; 3 plates; 2 text-figures. 1927. Price 4*s. net.*

The Geology of the Rossendale Anticline. (Explanation of one-inch Sheet 76 (Rochdale): England). By W. B. Wright, M.I.M.E., R. L. Sherlock,

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D.Sc., A.R.C.Sc., D.A. Wray, M.Sc., W. Lloyd, B.Sc. and L. H. Tonks, M.Sc. 182 pp.; 7 plates; 38 text-figures. 1927. Price 4*s.* 6*d. net.*

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales). Part I. Lower Palaeozoic and Lower Carboniferous Rocks. By C.B. Wedd, B.A., B. Smith, M.A., Sc.D., and L. J. Wills, M.A., Ph. D. With a contribution by G. W. Lamplugh, F.R.S. 179 pp.; 4 plates; 14 text-figures. 1927. Price 4*s.* 6*d. net.*

The Country between Stafford and Market Drayton. (Explanation of one inch Sheet 139: England and Wales). By T. H. Whitehead, M.Sc., A.R.C.Sc., E. E. L. Dixon, B.Sc., A.R.C.Sc., R. W. Pocock, M.Sc., T. Robertson, B.Sc., Ph.D., and T. C. Cantrill, B.Sc. 128 pp.; 5 plates; 5 text-figures. 1927. Price 3*s.* 6*d. net.*

The Geology of the Country around Ipswich. (Explanation of one-inch Sheet 207: England). By P. G. H. Boswell, D.Sc., Professor of Geology in the University of Liverpool. 121 pp.; 4 plates; 25 text-figures. 1927. Price 3*s.* 6*d. net.*

Scottish Memoirs published in 1927

Summary of Progress—*see* p. 18.

The Oil-Shales of the Lothians. *Third Edition.* Part I. The Geology of the Oil-Shale Fields. By R. G. Carruthers. Based on the work of H. M. Cadell and J. S. Grant Wilson. Part II. Methods of working the Oil-Shales. By W. Caldwell. Part III. Chemistry and Technology of the Oil-Shales. By E. M. Bailey. Part IV. History of the Scottish Oil-Shale Industry. By H. R. J. Conacher. 274 pp.; 12 plates; 75 text-figures. 1927. Price 5*s.* 6*d. net.*

English Memoirs in the press at the close of 1927

Palaeontology. Vol. I. Part 5. Plectambonites and some Allied Genera.

Palaeontology. Vol. III. Part I. The British Carboniferous Producti. II.—Productus (*sensu stricto*); Semireticulatus and Longispinus Groups

Wells and Springs of Somerset.

Wells and Springs of Warwickshire.

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales). Part II. Coal Measures and Newer Formations.

The Geology of the Country around Woodbridge, Felixstowe, and Orford. (Explanation of one-inch Sheets 208 and 225: England).

The Geology of the Country near Hastings and Dungeness. (Explanation of one-inch Sheets 320 and 321: England).

Scottish Memoirs in the press at the close of 1927

The Geology of Arran.

Special Reports on Mineral Resources

A second edition of Dr. Sibly's memoir on the Iron Ores of the Forest of Dean and South Wales, revised thoroughly after a careful examination of both districts by Mr. W. Lloyd, was the only volume of this series that made its appearance during 1927. Visits have been paid by the field geologists to several lead, zinc and copper mines when active developments were in progress, but until the current editions of these memoirs are sold out it is not necessary to replace them, as the new information which is being received is

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not sufficiently important to warrant that step. Mr. Dines, who is a trained mining engineer, has been engaged for some time in revising the mining notes and mineral lodes on our set of mines maps of Cornwall and Devon so as to make sure that new information is correctly recorded as it is received. The oil-shales memoir previously mentioned might almost be regarded as a volume of this series, and it may be noted that the map illustrating that memoir has been very carefully brought up to date by incorporating all the details received during the last ten years from the engineers of Scottish Oils, Ltd., who have been most willing to help. The manuscript of a Special Report on Ball Clays has been written by Dr. A. Scott of the Pottery Laboratory, Stoke-upon-Trent.

Water Supply Memoirs

No memoir on water-supply has been published during the year. This is principally due to the pressure of other work. On the other hand, a very large amount of manuscript was being prepared for press during the latter part of the year as will be seen from the fact that the following memoirs are in hand :—

Wells and Springs of Somerset (in page proof)
Wells and Springs of Warwick (in galley proof)
Wells and Springs of Sussex (printing)
Wells and Springs of Derby (in preparation)
Wells and Springs of Worcestershire (manuscript under revision).

The following memoirs of this series are also in hand but are not yet in an advanced state :—

London Wells (second edition)
Wells and Springs of Gloucester (manuscript under revision).

This series of publications appeals only to a limited public but has a steady sale, as witness the fact that the Sussex memoir has now sold out, and the Supplement to that memoir is also in demand and a new volume on the county containing many important sections recently obtained and not previously published is now in the press. In the memoirs enumerated above great care is taken that both the records of the wells and their exact situation are thoroughly checked as otherwise the information given loses a great part of its value.

The enquiries regarding water supplies from deep wells received from borers and engineers continue to be very numerous, and in turn we receive from the principal firms engaged in this work very full information about new wells. No opportunity is lost of making additions to the large collection of well records in the possession of the Survey. This constitutes a mass of information of the highest possible value for health, town-planning and industry, and though much of it is now published and available in printed form a very large amount is contained in our manuscript records, which, under the necessary precautions, are generally available, wholly or in part, to engineers and others who wish to make use of them. These records are frequently consulted by public departments. Apart

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altogether from their practical value as indications of water resources still available, they are of great use to the geologist as supplying particulars of the underground strata in the districts where they belong.

Inspection of Bores and Shafts

In last year's *Summary of Progress* (p.25) it was announced that under the Mining Industry Act, 1926, powers had been given to the Geological Survey of Great Britain to examine all mining plans of working mines and receive compulsory notification of borings and shaft-sinkings intended to reach a depth of 100 feet or more.

By the willing co-operation of the Mining Industry we are now in receipt of notification of all important borings for minerals and it has been arranged that one or more officers of the Survey will visit all bores that are of any significance, will check the records and take such specimens of rocks and fossils as are necessary.

Two experienced technical assistants, Mr. Templeman (in England) and Mr. Manson (in Scotland), have been allocated entirely to this work. They obtain the records, check them, and deposit them in our registered collections. If the borings show new points of geological interest they are also visited occasionally by the geologists who are specially concerned with the district. The number of specimens of rocks and fossils obtained in this way is gradually increasing, and the value and reliability of the bore records for geological purposes is very much enhanced. Often the borer or mining engineer is concerned only with one bed, say a coal seam or a bed of iron ore. To him the other rocks may appear meaningless; but to a geologist the whole core is significant and many details are of interest that would escape the attention of the severely practical observer. It is found, however, that the borers and engineers are often much interested in the geological interpretation of the bores and welcome the visits of geologists who are prepared to discuss the general inferences that arise from the work.

The number of bore notifications received up to 31st December, 1927 was, England 38, Scotland 70, and a large number of visits was paid to them both by the geologists and the technical assistants. It is believed that no really important information has been lost and that much has been learned that might otherwise have escaped our attention. The mining industry has not been in a very prosperous state during the year under review and it is probable that with a return of prosperity the amount of boring and shaft-sinking will increase considerably.

Hitherto access to plans of mines and records of bores has been possible only with the permission of the engineers or proprietors of the workings. It is gratifying to be able to state that very seldom has permission been refused and then only for very serious reasons such as business negotiations or impending litigation. The Survey is now in a more secure position, though in actual practice this does not matter very much. The principal gain is that all mineral bores

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are notified and all working plans are open to examination. Consequently much time will now be saved that was formerly occupied in correspondence, requests for permission, and so on. The condition of absolute secrecy imposed on Survey officers, except where sanction has been obtained for publication, remains as stringent as before; but this has seldom proved a very serious impediment except where the best possible reasons could be adduced in favour of it.

Soil Mapping

Further progress has been made in co-operative work between our field geologists and the soil experts under the aegis of the Development Commission, the Ministry of Agriculture and Fisheries, England, and the Board of Agriculture, Scotland. A system of notation for variations of soil texture suitable for adoption on our six-inch field maps is still under consideration; the present method might undoubtedly be made more complete and comprehensive. Photographic copies of six-inch maps of certain districts have been supplied to some of the agricultural officers and a considerable development of this kind of co-operation seems possible in the future. In September a joint meeting of soil-experts and field geologists was held near Scarborough, with the object of working out some practical problems together under the best possible conditions. The Survey was represented at this conference by Messrs. Eastwood, Wray, and Simpson. The results were of great interest and seem to show that in some areas at any rate the Geological Survey's drift maps might be of considerable value to soil mappers. These maps are in no sense agricultural or soil maps, but in the hands of an agriculturalist who understands them they have considerable value as indications of the varieties of soil likely to be met with and their probable distribution and origin.

A very interesting piece of work has been done in the Kilmarnock area where Professor Berry and his assistants have taken in hand the survey of a district corresponding to one-inch geological Sheet 22 and have prepared a map showing soils classified according to their textures. Our new geological sheet is being engraved for publication and advance copies of the 'drift' edition were supplied to the soil workers. A comparison of the two sets of maps shows many interesting points of similarity and not a few striking differences. It is too soon as yet to attempt to formulate any conclusions, but the work is distinctly of great promise. The form of publication which will be adopted is not yet decided but Professor Berry has promised to contribute a chapter on 'soils' to the memoir on that district which is now in preparation, and this will be the first contribution to this subject that the Survey has issued for many years.

The Geological Survey has also continued to give assistance to the officers of Agricultural Colleges who desire to obtain more complete geological drift maps of areas in which they were making special researches. Dr. Ogg's work in East Lothian is being followed

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with great interest and all help that the staff in Edinburgh can give to the agricultural soil investigators is being freely accorded.

Geophysical Surveying

Much attention has been directed of recent years to the use of geophysical methods for geological surveying. As a rule the object aimed at has been the detection of deposits of economic minerals such as oil, iron ores, salt and lead ores. The methods employed are very numerous, being gravitational, electrical, magnetic, seismic, acoustic, and by means of wireless rays. Each of these methods has its special applications and is suitable for the attack of problems of a definite kind and they are sometimes used in conjunction as one of them may supplement the information gained in other ways. It may be stated that as a general rule these new devices are in the hands of commercial companies and exploratory syndicates and the results obtained are very frequently not published or available to other scientific workers. Special schools have been established at some Continental universities for training and instruction in these operations and a considerable literature exists, though mostly restricted to the scientific groundwork on which the practical processes are founded. The value of these methods has been abundantly proved in many instances, but in others the geophysical surveys require still to be supplemented and definitely tested by boring, mining or excavation. They have certainly awakened widespread interest among economic geologists and strong expectations have been aroused that they will ultimately prove of the greatest practical value. As yet few official or national Geological Surveys have done much work of this kind, but in Russia, Sweden and Spain they have been employed by the state surveys and reports of the results have been published. In each of these cases it has been found that in skilled hands and under adequate supervision these geophysical surveys are of considerable utility in locating deep-seated structures and mineral deposits. Our attention was specially directed to these means of exploration by Sir John Cadman, a member of the Geological Survey Board, and by his kindness and that of the Directors of the Anglo-Persian Oil Company Dr. McLintock and Mr. Phemister were allowed to visit Persia and join the Company's geophysical survey parties in the field. A report of the operations was contained in last year's *Summary of Progress* and the impression produced was so favourable that it was decided as soon as possible to undertake researches of this nature in Great Britain. We are also greatly indebted to the kindness of Mr. E. Lancaster-Jones and Captain H. Shaw, officers of the Science Museum, South Kensington, who had had considerable experience of this class of work and have proved very helpful in many ways.

Means were found early in 1927 to purchase an Eötvös balance of the type made in London by Messrs. Oertling and constructed under the supervision of Captain Shaw and Mr. Lancaster-Jones. This was supplied early in May and Dr. McLintock and Mr. Phemister

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proceeded at once to test and calibrate the instrument in the crypt of the Geological Museum and to practise the manipulations before proceeding to the field. It may be said that the instrument has proved very satisfactory and has worked well in every respect.

A field party was then got together consisting of the two geologists above named with two technical assistants and a labourer. Surveying instruments for the necessary surface surveys were purchased, as well as tents, transport and all necessaries for a field unit of five or six men.

The problem investigated was not the usual one of finding new deposits or concealed structures by means of this instrument. On the contrary it was decided to apply the instrument to the examination of certain districts where it was known that geological structures or subjacent rock masses were present that should produce a notable effect on the balance. In this way it was hoped to ascertain the exact field in which its employment was justified, and if possible the limitations of the method. Although qualitative results were all that was expected in the earlier experiments it was considered possible that in favourable circumstances quantitative accuracy might also be approached. The direct object in view, however, was to learn thoroughly the methods of surveying and to put the balance to the test over known structures before proceeding to the examination of geological problems which were as yet partly or wholly unsolved.

Our first object, accordingly, was to find a suitable problem, and after considering a number of structures and making a careful preliminary inspection of the ground it was decided to begin with a survey of the underground extension of the well-known Swynnerton dyke in Staffordshire, where its course is buried beneath drift and possibly also Triassic Marls. For this purpose a situation was selected that was not too inaccessible, and where the ground surface was reasonably level and free from major irregularities that would need careful survey and elaborate calculation before the geophysical results could be reduced to final form.

The field work was begun in July, and though the weather was very wet eighteen stations were finished in a little less than a month. The preliminary results were calculated in the field and subsequently thoroughly revised after the return to headquarters. No difficulties were experienced with the balance, which worked well throughout, but for greater accuracy observations were made only after sunset and the photographic method of registration was not employed. All observations were made visually and repeated till constant readings were obtained.

The results were in every way satisfactory and a preliminary account of them was published in the *Mining Magazine* for January, 1928. For further details the reader is referred to the Appendix I, (Part II). We are indebted to the editor of the *Mining Magazine* for the loan of the *cliches* from which the illustrations are printed. These operations showed that the balance is a perfectly practical

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instrument, and though the manipulations and calculations are certainly delicate and complex a field unit can be trained to do geophysical work with this instrument in a comparatively short time.

After the completion of this campaign the instruments were brought back to London and overhauled and adjusted. It was then decided to select a new problem for investigation that presented more difficulties than the previous one. For this purpose it seemed likely that a buried channel filled with drift, clay and gravel, would prove satisfactory. This has, of course, well-defined practical bearings, as in coalfields where shallow seams are being worked channels such as these require to be located if possible before they are encountered in mining operations.

To the north-west of Glasgow the River Kelvin in pre-Glacial times flowed in a deep valley which is now entirely filled with Glacial deposits. The present surface is nearly a flat plain, but borings put down in search of minerals have shown that the old channel is about a mile broad and not less than 300 ft. deep in its deepest portion. Moreover, it was known from the records of these borings that a hummock of rock rises from the floor of the channel and reaches within 70 ft. of the surface, though nowhere exposed to view. On each side of this hummock there is a deep drift-filled valley. As the surface conditions were comparatively favourable and as the main elements of the problem were already known through the bore records, this seemed in every way a good opportunity for putting the balance to a further test. The difference between the specific gravity of the Carboniferous sandstones and shales forming the banks of the channel and the rocky protuberance and the specific gravity of the sands and gravels (probably water-logged) that occupy the channel seemed likely to be sufficient to yield measurable results.

The instruments were transferred in November, and a camp established at Drumchapel, eight miles north-west of Glasgow. The personnel of the unit was mostly the same as that which had been at work in Staffordshire though some of the English technical assistants were replaced by Scottish. The weather at first was favourable and at an early stage it was clear that the geophysical survey was going to provide evidence of a perfectly definite order. The buried rocky knoll was soon located and by the close of the year about one third of its circumference had been mapped out. It proved to have, however, a considerably different shape from that provisionally deduced from the scanty records obtained in the borings. Its configuration is that of a mass elongated in a north-west and south-east direction with steep sides. Before the end of the year its north-west limits had not yet been defined. Some idea has also been obtained in a preliminary way of the relative steepness of the slopes that bound the rock knoll and adjacent faces of the buried channel. The investigation is going to be carried on as long as the results obtained seem worth the trouble and time expended, but it is not at present possible to give more than a very incom-

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plete account of them. Undoubtedly in such questions as these the evidence of surveys with the Eötvös balance may be very useful. The work is difficult, slow and costly, but the only other means of proving the ground would have been by borings and the geophysical survey is much more complete and gives a far better general solution, though perhaps less strictly accurate in detail, than a number of deep bores.

No attempt has yet been made to try the other kinds of geophysical work that are now being employed for geological purposes; it is possible, however, that after the Eötvös balance has been tested on a variety of geological structures some of the electrical, magnetic and other devices may be similarly experimented with. It may be noted that the Australian Research Council has instituted a programme of geophysical exploration in Australia. The Department of Scientific and Industrial Research is interested in this and has undertaken to give all possible assistance. A committee was appointed to consider programmes and of this committee Dr. McLintock was a member[1]. The Australian Research Council has sent one of its officers, Mr. Lewis, to study the use of the Eötvös balance under Dr. McLintock and he has put in a period of preliminary work in the Geological Museum and a period of field work at Drumchapel which will render him familiar with the operations necessary for conducting surveys of this class.

New Scottish Headquarters

For the past 22 years the Geological Survey has had its Edinburgh office at 33 George Square, in a large house that was at one time occupied by the famous artist Sir Noel Paton. As two large studios and a corridor had been erected in the garden excellent accommodation was provided for the palaeontological collections with abundant light for working purposes, and both in situation and in capacity that house was excellent. The property, however, was acquired by the University of Edinburgh, who have now decided to convert it into hostels for students. New offices consequently had to be obtained and after considerable search H.M. Office of Works decided to purchase a roomy villa on the south side of Edinburgh rather more than a mile from the previous headquarters. This has the disadvantage of greater distance from the Royal Scottish Museum where our exhibited collections are displayed in a special gallery; on the other hand, it is nearer the University geological department which is now at the King's Buildings, about half a mile from Southpark, the new office of the Geological Survey. At the close of the year workmen were busy installing central heating, electric light, telephones, etc., and it is expected that the transfer to new quarters will take place in April or May, 1928.

[1] Geophysical Surveying. Report of a Sub-Committee of the Committee of Civil Research. (Empire Marketing Board), Nov. 1927, pp. 1-21.

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Staff Changes

Mr. T. C. Cantrill, District Geologist, has taken his retirement, and Mr. C. H. Dinham will now superintend Mr. Cantrill's unit. Owing to his long experience in South Wales, North Wales and the Midlands, Mr. Cantrill's services were highly valued and his extensive knowledge was backed by sound judgment and great diligence. The Survey has lost one geologist, Mr. Maden, by death as the result of an accident. Two others have been incapacitated for a considerable time by illness. No addition has been made to the list of geologists during the year, but the establishment of technical assistants has been increased by two and that of the general assistants by one.

Mention should also be made of the death of Mr. J. B. Hill which took place in London on 18th December, 1927. Mr. Hill had served in Argyllshire, Cornwall, South Wales and other districts and his best known contributions to Survey literature are *The Geology of Mid-Argyll* (1905), *The Geology of the Sea-board of Mid-Argyll* (1909), *The Geology of Falmouth and Truro and of the Mining District of Camborne and Redruth* (1906), and *The Geology of the Lizard and Meneage* (1912). He was transferred from the Geological Survey of Great Britain to the Ministry of Health in 1911 and served as geological adviser for 11 years. Mr. Hill had all the qualities which make a successful field geologist, good health, great powers of observation, steady industry and intense interest in the subject. His colleagues always regarded him as a most valuable member of the staff in addition to being a pleasant companion and a shrewd judge of men.

Collaboration

The Survey has received professional assistance from numerous British geologists and palaeontologists during the past year and grateful acknowledgment must be made of their services. Dr. Sibly revised the proofs of the memoir on the Iron Ores of the Forest of Dean and Professor Boswell performed similar duties for his memoir on Ipswich. Messrs. Caldwell, Bailey and Conacher have passed the proofs of their contributions to the memoir on the 'Oil Shales of the Lothians.' Dr. Tyrrell has completed his manuscript of a memoir on the geology of Arran. Two palaeontological memoirs are in the press, one by Miss Muir-Wood and another by Professor O. T. Jones, and the authors have revised the proofs which are now nearly ready for publication. Mr. Osborne White has completed an account of the geology of the district around Ramsgate and Dover, and this memoir has not yet gone to press, but his memoir on the geology of Hastings was printed and on the eve of publication at the close of the year. Mr. Linsdall Richardson has given much help in the preparation of his memoirs on the water-supply of Somersetshire and Warwickshire, which are passing through the press. His manuscript on the geology of the Moreton-in-the-Marsh Sheet has also received some attention.

Miss E. M. Lind Hendriks has completed the manuscript of a

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list of Classified Geological Photographs specially selected as useful for teaching and demonstration purposes, and Miss Eileen M. Guppy has assisted the Director in preparing a manuscript on tested British roadstones. Miss M. E. Odell has spent much time in improving the registers of our most important fossil collections. Dr. John Horne continues to check and correct the clean-copies and proofs of the maps of the Southern Uplands of Scotland which are being published with revisions due to Dr. Horne and Dr. Peach.

Further assistance in the nomenclature of critical British fossils has been received from Dr. Gertrude Elles (graptolites), Professor Hawkins (echinoderms), Professor Trueman (mollusca), Mr. W. S. Bisat (goniatites), Professor Lang and Dr. Walton (Palaeozoic plants), Professor D. M. S. Watson (vertebrate fossils), Mr. S. S. Buckman (Jurassic cephalopods), and Dr. Stanley Smith (Palaeozoic corals).

Professor R. A. Berry is writing an account of the soils of the Kilmarnock area for inclusion in the memoir on Sheet 22 (Scotland), and Dr. Alex. Scott has prepared a special report on Ball Clays.

Royal Commission on Museums and Galleries

On the 1st July, 1927, a Commission was appointed " to enquire and report on the legal position, organisation, administration, accommodation, the structural condition of the buildings and general cost of the institutions containing the National collections situate in London and Edinburgh," etc.

The Director of the Geological Survey prepared and submitted a memorandum on the Museum of Practical Geology and the collections contained therein. Subsequently he appeared before the Commission and gave evidence.

The following question was asked in the House of Commons on 22nd December, 1927 :—

Sir Charles Oman asked the Under-Secretary of State for the Home Department, as representing the First Commissioner of Works, what are his intentions in view of the dangerous condition of the Museum of Geology in Jermyn Street ?

The Under-Secretary of State for the Home Department (Lieut.-Colonel Sir Vivian Henderson) replied : The Royal Commission on the National Museums and Galleries has represented that the present conditions in Jermyn Street are unsatisfactory from every point of view, and that the transfer of the Geological Museum to an appropriate site in South Kensington should be made at the earliest convenient moment. The Chancellor of the Exchequer and my Noble Friend endorse this view, and hope to give effect to it as soon as financial circumstances permit. (Parliamentary Debates, House of Commons, Vol. 212, No. 144, column 561).

Palaeontology

ENGLAND AND WALES.—The fossils added to the collections during the year numbered 8426 specimens ; of these, 2587 were

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obtained by purchase and by presentation. Conspicuous among the special collections thus acquired was a set of well localized lamellibranchs from various zones of the Inferior Oolite, obtained from Mr. L. Richardson. Dr. C. A. Matley presented a further series of Ordovician fossils from Carnarvonshire.

The examination of the fossils collected in the course of current Survey work has been carried out by Mr. Pringle and Mr. Chatwin, as well as by specialists who are not members of the staff. Dr. Kitchin has spent much time in editorial duties, and he has also been engaged in curatorial and supervision work. Early in the year he paid a visit to the Edinburgh office to confer with Mr. Macgregor and Dr. Lee in regard to matters concerning palaeontological work.

Mr. Pringle identified specimens obtained from localities in 14 sheets in which work was in progress, and furnished completed lists of determinations relating to 8 sheets. He visited sections in the districts of Brampton, Wolverhampton, Shrewsbury, and Merthyr Tydfil, now undergoing revision, and gave assistance to those engaged in surveying the ground. In conjunction with Dr. R. Crookall, he reported on an examination of sections in the Coalbrookdale coal-field, submitting a joint contribution to the memoir on the Wolverhampton Sheet.

Mr. Chatwin prepared the results of his work on the fossils obtained in the Guildford area, for inclusion in the forthcoming memoir (Aldershot). In this connexion he studied further material from the Netley Heath Gravels (specimens presented by Mr. W. Wright and others collected by Mr. F. H. Edmunds). Mr. Chatwin visited sections in Surrey and Sussex and examined part of the core of the Wokingham boring. He also examined and reported on several collections of fossils in private possession, with a view to their acquisition. With the naming and registration of an extensive series of Inferior Oolite fossils, he completed the curatorial work on the Hudleston Collection. He revised four cases of Chalk fossils in the museum, with the assistance of Mr. S. W. Hester, selecting a typical series for arrangement on a zonal basis, and revising the nomenclature.

The fossil-collecting incidental to the current Survey work was carried out chiefly by Mr. Hester, and this entailed visits to localities in Sussex, Surrey, Cumberland, and Lancashire. The work in Cumberland also included the collecting of a representative series of rock-specimens from the Carboniferous system. While in Cumberland, Mr. Hester was assisted by Mr. W. Dewar, who became attached to the department as a General Assistant in June. Since the diversion of his services to the work of inspecting and obtaining records of borings and shaft-sinkings, Mr. A. Templeman has been unable to take any share in the collecting of fossils required during the ordinary sheet-surveying.

During a considerable part of the year Mr. S. W. Morgan gave assistance to Dr. R. Crookall in work connected with the Kidston Bequest of fossil plants.

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In view of the congestion of space in the working-rooms of the Palaeontological Department, it has been necessary to spend much time in carrying out a rearrangement in parts of the stored collections. Mr. Templeman's services have been available from time to time for assistance in furthering this work.

Special attention has been devoted to the important work of registering fossils, and in order to ensure the more steady growth of the registers the services of Miss M. E. Odell, B.Sc., were utilized for about seven months. During that time Miss Odell made good progress, and latterly she confined her attention to those portions which were still unregistered of the large collection handed over some years ago to the Geological Survey by the Geological Society of London.

Many enquiries have been answered, and assistance has been given to numerous research-workers. The specimens of fossils sent out on loan for the purposes of investigation numbered 2177.

SCOTLAND.—1143 specimens of fossils were collected during the year from the Palaeozoic rocks of Scotland and Northumberland. The Scottish specimens were obtained from the Ordovician of Ayrshire, the Old Red Sandstone of the Orkneys, and the Carboniferous of Ayrshire, Berwickshire, Clackmannanshire, Edinburghshire, Fife, Linlithgowshire, and Stirlingshire. The Scottish Carboniferous fossils were found almost exclusively in the cores of borings, while those from the Coal Measures of Northumberland were collected in natural sections.

The collecting of the material from the Old Red Sandstone was carried out by the officers of the Orkney unit, and the remainder by Messrs. Tait, Manson, Eckford, and Strachan, Mr. Manson dealing with most of the borings.

Apart from the Ordovician and Old Red Sandstone fossils (submitted to Dr. G. L. Elles and Prof. D. M. S. Watson, respectively) and the fossil plants, the examination of the specimens obtained was carried out by Dr. G. W. Lee, who also wrote the palaeontological part of the Ardnamurchan Memoir.

New Jurassic exhibits have been added to the Survey collection in the Royal Scottish Museum, and progress has been made in the revision of the obsolete naming of the old exhibits.

Palaeobotany

The chief item of indoor work has consisted in the completion of the catalogue of fossil plants in the Kidston Collection, and this is now ready for the press. Dr. Crookall has also given assistance in checking the lists of plants appearing in the various sheet memoirs issued during the year and those at present passing through the press. Much time has been spent in the identification of the numerous plants collected from localities in the areas covered by Sheets 22, 23, 28, 76 and 85, and from various boreholes which have been under examination. In the course of this work Dr. Crookall has

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prepared and added to the collections 59 photomicrographs and 40 microscope sections.

Thirty-six hand-specimens of fossil plants and 44 microscope slides have been loaned to Dr. R. Florin of Stockholm, and 130 sections of coals to Miss E. Janisch of Cambridge University for research purposes. A selection of 283 microscope slides and 120 hand-specimens have been acquired by purchase and placed in the collections.

Visits have been made, in company with Mr. J. Pringle, to the Coalbrookdale district and to the area represented by the Merthyr Sheet (No. 231), and joint accounts of the palaeontology of the Coal Measures are in course of preparation.

Petrography

The Petrographer has continued with Mr. Richey his work on the Tertiary igneous rocks of Ardnamurchan, and the petrographical description of this region is nearing completion. The descriptive petrography of the Ordovician igneous rocks of the Oswestry district has been completed. Reports have been drawn up on an interesting suite of Lower Carboniferous lavas and tuffs occurring near Cockermouth on the northern side of the English Lake District, and preliminary petrographical work has been carried out on the complex igneous rocks of the Wrekin and adjoining districts. Consequent on the re-survey of the Cheviot Hills preliminary work has been done on the granite, lavas, dykes and metamorphic rocks of that region. The Petrographer has dealt with many inquiries of an official and unofficial nature, identifying and reporting upon material submitted by Survey officers and private individuals. He has furnished information concerning matters of archaeological interest, and, as usual, has reported on material submitted by such other government departments as the Road Board, Government Laboratory, Woolwich Arsenal, and Admiralty, as well as by public bodies.

In the Scottish office Dr. Read and Mr. Phemister have continued their work on the igneous rocks of Lanarkshire (Sheet 23), and Dr. Read has carried out a preliminary examination and classification of the metamorphic rocks of Sutherlandshire (Sheets 108 and 109). Dr. Read has also named and classified some dyke-rocks of the Southern Uplands (Sheet 8).

Mr. MacGregor has completed his detailed account of the post-Old-Red-Sandstone lavas and minor intrusions of Ayrshire for the forthcoming memoir on Sheet 22.

Mr. Bailey has continued his petrographical work on the gneisses of Coll, and Dr. Tyrrell of Glasgow University has completed his account of the petrography of Arran for the second edition of the Memoir on that island.

The number of sliced rock specimens in the collections deposited in London is as follows :—

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English	...	14,113
Scottish	...	26,301
Irish	...	447
Foreign	...	2,743
Total	...	43,604

This represents an increase of 1,140 in the registered sliced rocks during the year. Of the corresponding sections, 806 were made in the English office, and 334 were registered to be made in Scotland.

Dr. J. Horne has kindly presented a suite of sections of rocks from Aberdeenshire, and these will, after registration, be incorporated in the Scottish collection.

Photography

Mr. J. Rhodes has been employed taking geological photographs in the districts of Shropshire, Cumberland, Suffolk, Staffordshire and Kent, to the number of 366.

The number of registered negatives is now as follows :—

English Photographs	...	4,216
Photomicrographs	...	1,861
Miscellaneous	...	1,699

Mr. Rhodes has made 1,639 prints from Survey negatives mainly for incorporation in the Reference-albums but including 58 for reproduction in Survey memoirs, and an addition of 213 lantern-slides has been made to the collection now in process of formation.

Fifteen enlargements of geological subjects were made for exhibition at the meeting of the British Association at Leeds. Mr. Rhodes has also mounted 1,388 prints and 1,249 descriptive forms for use in the English and Scottish Survey libraries.

The albums are now completed to the following registered numbers, each photograph being accompanied by its corresponding descriptive form.

English Series	...	3,819
Scottish Series	...	3,003

In Scotland Mr. W. Manson has taken 34 negatives of interesting geological views.

The catalogue of Classified Geological Photographs prepared by Miss Lind Hendriks is completed and ready for the press.

Chemistry

Samples have been sent from Cornwall, Ayrshire, Bute, Lanark and Sutherland for quantitative analysis. The numbers of analyses entered up-to-date in the department's records total :——

English	...	340
Scottish	...	485
Irish	...	2

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Welsh	...	...	55
Others	...	...	46
Total	...	...	928

Twenty-seven of the above samples have been analysed during the year and twelve others are in course of completion. Survey Officers have required eight qualitative examinations and many enquiries from various sources have received attention.

The Chemist has, on several occasions, given technical advice to the Officers of the Fuel Research Station with reference to methods for the analysis of coal ashes and of the sintered test cones obtained in the determination of the refractory characteristics of the same materials.

Dr. A. M. Heron (Geological Survey of India) has spent several months in this department, doing analytical work under the direction of the Chemist, on specimens collected in India.

The comparative resistivity of several types of British glassware has been practically tested in the laboratory, by long periods of normal use in the course of routine analysis, testing being still continued in order to ascertain which variety would be most suited for work with inorganic reagents.

Museum of Practical Geology

No changes of importance have been made in the Museum during the past year, as pending removal to South Kensington little can be done to initiate alterations or improvements. The total number of visitors during the year was 20,968, of whom 1,389 were Sunday visitors. Thirty-two demonstrations were given by officers of the Museum and Survey to schools and institutions, the aggregate attendance being 615. A special exhibit was prepared for the meeting of the British Association at Leeds in September.

Certain wall cases and table cases have been cleaned and the registration of the collections has been carried forward so far as other duties allowed. Of the Ludlam mineral collection, 1,451 specimens, and of the Lindsey collection 716 specimens were registered and card indexed. Rock sections were prepared, by museum officers, to the number of 89, including several of building stones for the Building Research Station. The exhibit of tested road-stones has been transferred, cleaned and partly re-labelled. Mr. Chatwin has revised several cases of Cretaceous fossils.

For a considerable part of the year the Curator was engaged in geophysical survey work.

The temporary electric lighting has been overhauled. The congestion arising from the lack of space for staff and collections, and the obstruction due to the scaffolding and timber supporting structures have continued to impede the usefulness of the library. During the past year the additions to the library comprised 396 volumes of independent works, 2,879 volumes and parts of

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serials, 693 maps, 299 pamphlets and 514 Geological Survey photographs. The library is expanding but is much hampered by lack of space. It continues to be much used by mining engineers, geologists and other professional enquirers, and the attendance of students wishing to consult maps and geological books is constantly increasing.

List of Donations during the year 1927

ARKELL, D. J., ESQ.—Specimens of strontianite.

ASHCROFT, F. N., ESQ., M.A.—Specimens of prehnite from Switzerland.

BARROW, G., ESQ., F.G.S.—A specimen of the Basement Bed of the London Clay (with fossil shells) from Lane End, High Wycombe, Buckinghamshire.

BOLTON, H., ESQ. D.Sc., F.G.S.—A series of marine fossils from the Coal Measures of the Bristol coalfield.

BROWN, G. F., ESQ.—A series of Chalk fossils, chiefly Echinoderms, from various localities in Surrey.

COLLETT, H. E., ESQ.—Rough sapphire crystals, from Queensland, Australia.

COOKE, H. C., ESQ. (Canadian Geological Survey).—Four specimens of dalmatianite, from the Annular Gold Mine, Western Quebec, Canada.

DAVIS, A. G., ESQ.—A series of Chalk fossils from the rock-band in the base of the *Micraster cortestudinarium* Zone, from various sections in North-east Surrey.

DEWEY, H., ESQ., F.G.S.—A series of bones and teeth from the Pleistocene of Plymouth Caves, Devon.

DIX, MISS E., M.Sc., and A. E. TRUEMAN, D.Sc., F.G.S.—Eighty-five specimens of rocks and fossils from boreholes in the Cwmgorse valley—75 from No. 1 borehole, 10 from No. 2 borehole.

DUGDALE, G. R., ESQ.—Native gold in talc and telluride gold ore, from Kalgoorlie.

DUNBAR, MAJOR R. M.—Gold-bearing quartz from Masai Province, Kenya Colony.

FLEMING, J., ESQ.—Tourmaline, cut stone, particoloured.

GARWOOD, PROFESSOR E. J., Sc.D., F.R.S.—Two specimens of basalt and one tuff specimen from Cumberland; also three basalt specimens from Roxburgh.

GIROUARD, COLONEL SIR PERCY, K.C.M.G., D.S.O., R.E.—Two Ammonites from 30 ft. above the base of the Chalk Marl, at 50 ft. above O.D., at Asheacham House, Beddingham, Sussex.

GOODENOUGH, CADET F. C., R.N.—A flint nodule containing the rare sponge *Aulaxinia costata* Hinde, from the Quadratus Zone of Whiteparish (about 10 miles from Salisbury), Wiltshire.

HAYES, DR. A. O.—A series of twenty-five specimens to illustrate the occurrence of iron ore at Wabana, Newfoundland.

HENDRIKS, MISS E. M. LIND, B.Sc.—Three rock specimens from Mullion Island, Cornwall.

HEWITT, H. DIXON, ESQ., F.I.C.—Eight specimens of Lower Greensand fossils from boulders in the Thetford Glacial Gravels at Thetford Warren, Norfolk.

HORNE, DR. JOHN, F.R.S.—One hundred and fifty-six rock sections prepared from Scottish rocks.

JACK, G. H., ESQ., M.INST.C.E., F.R.I.B.A., F.G.S.—A specimen of *Pterygotus sp.* from the Old Red Sandstone of Abbeydore, south-west Herefordshire.

LANG, PROFESSOR W. H., F.R.S.—Plant remains from the Middle Old Red Sandstone of Loch Brora, Sutherlandshire, and Hillhead Quarry, Dalcross Station, Inverness.

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LESTER, DR. A. R.—A specimen of stichtite and asbestos.

MATLEY, C. A., ESQ., D.Sc., F.G.S.—A series of Ordovician fossils from the Lleyn district of Carnarvonshire.

MOORE, E. W. J., ESQ., B.Sc., A.I.C.—Two specimens of *Goniatites subcircularis* S. A. Miller, from the Bowland Shales (Spirale Zone) of Dinckley, Lancashire; and a portion of a bullion containing numerous specimens of *Homoceras striolatum*, var. *subglobosum* Bisat, from the Sabden Shales (H) in the Millstone Grit Series of Gill Beck, near Colne, Lancashire.

OGILVIE, SIR F. G., C.B., LL.D., M.A., B.Sc.—Specimens of fossil wood and fossil sponge from the Bargate Stone south of Shere, Surrey.

PORTER, R. H., ESQ.—Specimens of daphnite, cassiterite, wollastonite, orthoclase and mica, from Redruth, Cornwall.

POWELL, L. S. ESQ.—Specimen of talc from limestone, from a quarry N. of La Rochette, Savoy.

PRINGLE, J., ESQ., F.G.S.—A specimen of *Cleoniceras morgani* Spath (sp. nov.), from the Lower Albian (Regularis subzone) of Leighton Buzzard, Bedfordshire, figured by Dr. L. F. Spath, 'Ammonoidea of the Gault,' pl. xvii, fig. 7; pl. xviii, fig. 5. (Palaeont. Soc.).

PRESTON, MISS L. F. N.—A series of Roman marble specimens.

SANDISON, W. G. W., ESQ.—Chlorite rock from Shetland.

SMITH, H. H., ESQ.—Tourmaline in pyrite, from Meldal, Norway.

SOUTH AFRICA, THE DIRECTOR, GEOLOGICAL SURVEY, UNION OF.—A series of platinum-bearing rocks and other minerals and rocks from South Africa.

SPENCE, MESSRS. PETER, & SONS, LTD.—Specimens of leucite lava and sample of leucite from Farnworth, Widnes, Lancashire.

STATHER, J. W., ESQ., F.G.S., *per* T. SHEPPARD, ESQ., M.Sc., F.S.A. (SCOT.), F.G.S.—A specimen of *Inoceramus lingua* Goldfuss, from the Upper Chalk (Quadratus Zone) of White Hill Quarry, Bridlington, Yorkshire.

TRUEMAN, A. E., ESQ., D.Sc.—*see* MISS E. DIX.

TULLY, B. J., ESQ., F.G.S.—Brochantite with chalcanthite from Chile; also opal doublet, synthetic emerald, etc.

TUNNEL PORTLAND CEMENT COMPANY, THE.—A series of specimens illustrating the manufacture of Portland Cement.

WALKER, DR. F.—Four specimens from thick sill in Shiant Isles.

WARE, W. D., ESQ.—A series of Lamellibranchs from the Coal Measures of various localities in Glamorganshire.

WHITELEY, J. H., ESQ., F.I.C.—Vogtite-silica slag.

WOODS, H., ESQ., M.A., F.R.S., F.G.S.—A series of fossils from the Upper Chalk (Mucronata Zone) of Cottishall, Norfolk.

WORSFOLD, F. H., ESQ., F.R.I.B.A.—A specimen of fossil fruit from the London Clay of Tankerton Bay cliffs, Whitstable, Kent.

WRIGHT, W., ESQ., F.G.S.—Specimens of fossiliferous ironstone from the Gravels at Netley Heath, Surrey.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND AND WALES

1. LONDON AND SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
W. LLOYD, B.Sc.
F. H. EDMUNDS, M.A.
} Geologists.

DURING 1927 routine field work was suspended in order that parts of the geological lines in several districts could be revised for the preparation of colour-printed editions of hand-coloured maps. Memoirs describing these maps were written by Professor P. G. H. Boswell and Messrs. H. J. O. White and Linsdall Richardson. Mr. Dewey spent several weeks in inspecting and revising areas near Hastings, Dover and Ramsgate, and in preparing the maps and memoirs for the press. The following were published during the year:—Special Map of the London District, and the Ipswich map and memoir; while dry-proofs of the following maps were sent for engraving to the Ordnance Survey Office:—Aldershot; Dover; Ramsgate; Sudbury; Hastings and Dungeness. Colour-printed proofs of Felixstowe, Woodbridge, Hastings and Dungeness have been passed for printing.

The manuscript of the memoir on 'Aldershot and Guildford' by Messrs. Dines and Edmunds is nearly complete, while that on 'The Wells and Springs of Sussex' by Mr. Edmunds is ready for the printer.

Enquiries relating to water supply, building sites, soils and engineering problems have greatly increased in number, and upwards of 300 were dealt with. The principal related to proposed tube-railways under London and Southampton and tunnels under the Thames. The best sites for supplies of water for public bodies were also considered, while advice was given in numerous cases of foundering walls due to moving subsoil.

Mr. Dines spent some time in the early summer revising boundary lines of the drift deposits and in tracing the junction of the Middle with the Upper Chalk in the valley of the Dour and its tributaries near Dover. In the autumn he surveyed the drift deposits of the northern part of the Cotteswold Hills (Sheet 217), and has demonstrated the occurrence of boulder-clay and other glacial deposits as far south as the limits of the map.

In the spring Mr. Edmunds revised some boundary lines of the

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Purbeck Beds, the Fairlight Clays and the Ashdown Sand around Hastings and Battle, and was able correctly to represent the faulted area in Hastings town. Clear exposures showed the faults in the excavations for the Music Pavilion. Much assistance in this work was rendered by Mr. W. J. Lewis Abbott, who generously lent his notes and specimens, collected over a number of years, to the Survey.

In the summer Messrs. Dines and Edmunds surveyed the drift deposits west of Deal and in the Isle of Thanet. They mapped ridges of brick-earth overlying Coombe deposits and trending parallel with the coast near Deal. In this brick-earth, at Coldblow Farm, Walmer, a working-floor of flint implements was discovered, at a depth of 12 feet from the surface. The implements are chiefly scrapers and cores. North-west of Ramsgate a wide area covered with Thanet Sand has been mapped by Mr. Edmunds.

The occurrence in the Netley Heath deposits of isolated lumps of ferruginous sandstone with a fauna comparable with that of the Scaldisian and Poederlian horizons of the Upper Pliocene [1] led Mr. Edmunds to re-investigate the tracts of similar detritus at Lenham, Paddlesworth, Folkestone and Beachy Head. Mr. Lewis Abbott had collected such material at widely different heights on Beachy Head and the neighbouring Downs, and had published a paper in which it was described.[2] Mr. Edmunds had the opportunity of examining such ferruginous sandstone in the Beachy Head district, where it occurs in considerable quantity, and although it is largely unfossiliferous some blocks yielded marine fossils of Pliocene age. The fossils collected by Mr. Lewis Abbott are similar to the fauna at Lenham, but different from that at Netley Heath. The sections at Lenham on re-examination showed three deep pipes in the Chalk infilled with a disordered mass of sand and loam, in which are embedded numerous lumps of ferruginous sandstone and large noded and battered flints: casts of fossils also were found. In no sense can these materials be called beds: they represent merely the infilling detritus of solution cavities in the Chalk. Mr. Searles V. Wood (senior) was aware of this fact, for in an unpublished letter to Mr. Whitaker dated 26th February 1866, now in the possession of the Survey, he says "In regard to the Lenham fossils all that I know of them was given in Mr. Prestwich's paper where his opinion of their Crag character was more strongly expressed than my own. Many of the casts bore considerable resemblance to Crag species but I then considered and still consider it extremely hazardous to attempt to identify species by casts alone. My leaning would be to think them somewhat older than the Crag but what I observed concerning the fossils themselves was in reference only to their palaeontological character and not in reference to the age of the bed containing them which may be of *very recent* date and contain these casts only as derivatives—indeed they came from no actual deposit

[1] Chatwin, C. P., *in* 'Summary of Progress' for 1926 (*Mem. Geol Surv.*), 1927, p. 157.
[2] 'Pliocene Deposits of the South-east of England,' *Proc. Prehist. Soc. of E. Anglia*, vol. ii, 1915–16, pp. 180–186.

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but only from the red sand filling the pot-holes on the edge of the Chalk scarp."

Professor P. G. H. Boswell has examined the heavy minerals from the supposed Pliocene and some other deposits on the North and South Downs but finds the suites similar in every case with the exception of those from the ferruginous sandstone of Netley Heath.

Mr. Lloyd was transferred temporarily from the Manchester field unit to Torquay to revise the geology of that area with the view of preparing a second edition of the Torquay memoir, the first edition having run out of print several years ago. He has made good progress with the work, but recent advances in petrological study of the Devonian rocks, and the large number of new sections render rapid progress difficult.

H. DEWEY.

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2. MIDLANDS DISTRICT

T. C. CANTRILL, B.Sc., District Geologist.
C. B. WEDD, B.A.
R. W. POCOCK, M.Sc.
T. H. WHITEHEAD, M.Sc., A.R.C.Sc. } Senior Geologists.
T. ROBERTSON, B.Sc., Ph.D., A.INST.M.M., Geologist.

DURING the past season (1927) work has proceeded in the Shrewsbury district. North of the River Severn Mr. Pocock has mapped the area around Leighton, Wroxeter and Atcham, and south of the river around Shineton and Cressage. He has found it necessary to devote much time to the study of the complicated ground lying between the Wrekin and Charlton Hill. Mr. Whitehead has surveyed an area in the south-west corner of the Sheet (152), extending from Pontesbury southward.

Pre-Cambrian.—Mr. Pocock finds that the Uriconian rocks of the Wrekin have an average northerly dip of 45° and can be divided into groups of bedded ashes, conglomerates and rhyolites. The dolerite mass near The Cottage, at the northern end of the Wrekin, which Callaway regarded as "an ancient volcanic vent," maps out as a group of basic dykes, with an approximately north and south strike and steep easterly dip, cutting almost at right angles across the strike of the Uriconian ashes and conglomerates. In plan these dykes show a curved outcrop due to the high relief of the ridge. Above Wrekin Farm a dyke of similar character traverses the ashes on the north-west side of the Wrekin Fault, and another occurs within the mass of the rhyolite that forms the central and highest portion of the hill. As none of these dykes has been found to penetrate the Cambrian Quartzite, their pre-Cambrian age may be assumed with some confidence.

Uriconian rocks are thrown down by the Wrekin Fault all along the north-western side of the hill.

The Uriconian rocks of Charlton Hill, Overley and Wrockwardine have also been examined by Mr. Pocock. The Charlton Hill area is much complicated by faulting, in continuation of the line of the main Church Stretton fault-complex. The ashes and conglomerates of the hill are traversed by a set of felsite dykes. Similar dykes occur in the Wrockwardine area and at the south-western end of the Wrekin.

Volcanic rocks of pre-Cambrian age occur also in the area surveyed by Mr. Whitehead in Pontesford and Earl's Hills,[1] and at

[1] See W. S. Boulton, 'The Igneous Rocks of Pontesford Hill, Shropshire,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 450.

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the Lyd Hole to the east of these hills. This area contains, in addition, a considerable tract of sedimentary rocks belonging to the group called by Lapworth [1] the Wentnor Series, or Western Longmyndian. In the neighbourhood of Oakswood these rocks include three conglomerates, of which the lowest in apparent position contains mainly quartz and quartzite pebbles with only rare rhyolite fragments. The middle conglomerate contains pebbles of rhyolite and felsite to the extent of at least 50 per cent; whilst in the apparently highest also such pebbles are numerous, but of smaller average size. The dip in the area east of Pontesford and Earl's Hills is to east-south-east at angles ranging from 60° to 70°. This direction of dip has been found to persist for about 1½ miles along the strike and through at least 3,500 ft. of strata. As the outcrops are followed southward the dip becomes steeper until, at Paulith Bank, the beds are vertical. Farther south still the dip is west-north-westward at high angles.

These Longmyndian grits and conglomerates are traversed by dislocations that appear to be of the nature of tear-faults. These faults, and the joints parallel to them, have formed the channels whereby the barytes and copper-bearing lodes have been injected.

Cambrian.—Further examination by Mr. Pocock of the district between the Wrekin and Charlton Hill has revealed the presence of an important suite of Cambrian rocks comparable, in part, with those of Comley described by Mr. E. S. Cobbold,[2] who has undertaken the identification of the fossils from the present area and has visited most of the sections.

The Wrekin Quartzite, well known to occur at Rushton and at Charlton Hill, has now been traced through the intervening ground, where it rests on the Rushton Schist. In an old roadside quarry east of Rushton the lowest beds of the Quartzite, consisting of alternations of quartzite and dark grey shale, rest on an uneven floor of Uriconian felsite.[3]

Faulted outcrops of the Quartzite rest also upon the Uriconian rocks on the south-western and southern sides of Charlton Hill and of the small subsidiary hill to the south.

The Quartzite is overlain, near Rushton, by about 500 ft. of Lower Comley Sandstone, at the top of which, in the Charlton Hill branch of Dryton Brook, occurs a greenish micaceous sandstone containing abundant fragments of *Callavia callavei* (Lapworth) and other fossils, which suggest a reference to the Callavia Sandstone (Horizons Ac 1 & Ac 2 of Comley).[4]

Fragments of a fossiliferous calcareous grit from the same locality are comparable, in their lithological character and fauna,

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[1] Lapworth, C., and W. W. Watts, 'Shropshire,' in 'Geology in the Field,' *Geol. Assoc.* Jubilee Vol., 1910, p. 739 (see p. 748).

[2] 'The Stratigraphy and Geological Structure of the Cambrian Area of Comley (Shropshire),' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 551.

[3] Our attention was drawn to this fact by Mr. T. Hirst.

[4] A few fossils were collected, apparently from this locality, by Mr. J. Rhodes under the guidance of Prof. Charles Lapworth in 1892-3.

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with the *Microdiscus bellimarginatus* Limestone (Horizon Ac 3 of Comley). Other fragments of a dark granular phosphatic limestone with fossils may perhaps be referred to the Lapworthella Limestone (Horizon Ad of Comley).

These Lower Cambrian beds in Dryton Brook appear to dip southward at about 30° and are succeeded by Middle Cambrian glauconitic grits and shales. A calcareous block in the stream a few yards south of the last locality is crowded with well-preserved fragments of *Paradoxides* (perhaps two or more species) and other fossils. Mr. Cobbold considers that the fauna indicates Horizon Ba 1 of Comley, i.e., the *P. groomi* conglomerate and grit.

In the Rushton branch of Dryton Brook another calcareous bed yields a well-preserved fauna indicating, in Mr. Cobbold's opinion, a horizon high up in the Paradoxidian.

The Middle Cambrian beds have a lesser angle of dip than the Lower Cambrian, and may prove to be unconformable. They crop out again in the fields to the south of Charlton Hill.

Shales with *Acrotreta* and a brachiopod have been found on the east flank of Charlton Hill, but their horizon has not yet been determined.

A large block of black limestone, 'stinkstone,' in Dryton Brook, on the line of the Wrekin Fault, may be *in situ*. It is crowded with detached portions of trilobites and is provisionally referred by Mr. Cobbold to Zone No. 5 of Westergård [1] [Upper Lingula Flags]. This would indicate that the block belongs to a horizon well down below the Shineton Shales but above those with *Orusia lenticularis* and *Parabolina spinulosa*.

Purplish shales, probably Upper Cambrian, are exposed in Dryton Brook just north of the boundary of the Coal Measures of the Dryton Coalfield, i.e., just north of the Longwood-Dryton lane.

Mr. Pocock has also mapped the Upper Cambrian shales in the Leighton and Shineton areas, and Mr. Whitehead those in the Habberley valley as far as the southern border of Sheet 152 (near Gatten). Mr. Whitehead concludes that the junction of these Shineton (Habberley) Shales with the Longmyndian rocks to the east is probably a fault.

Ordovician.—A small area of rocks of Arenig age has been mapped by Mr. Whitehead near the south-west corner of the Sheet. These consist, in ascending order, of: (1) Stiper Quartzite, (2) Mytton Beds, flaggy sandstones and sandy shales, (3) Hope Shales, black and grey shales. The outcrops within the area surveyed have not yielded fossils owing to the cleaved condition of the rocks; but they form part of a larger area in which the succession was established by C. Lapworth.[2]

Ordovician shales crop out also in the valley east of Pontesford

[1] Westergård, A. H., 'Sveriges Olenidskiffer,' *Sveriges Geologiska Undersökning*, Ser. Ca., No. 18, 1922.

[2] See 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 37.

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and Earl's Hills, where they rest unconformably, and with a basal conglomerate, upon pre-Cambrian rocks. Further collecting is required before the precise stratigraphical position of these shales can be determined; but there is some evidence that they belong to a horizon lower than that to which they have hitherto been assigned.[1]

Silurian.—Mr. Pocock has surveyed three divisions of the Valentian (Arenaceous Beds, Pentamerus Beds, and Purple Shales) southward from the Carboniferous overlap at Wenlock Wood to the River Severn, and south of the river to Shineton Brook.

The basal portion of the Upper Llandovery Sandstone just enters the area mapped by Mr. Whitehead; but almost the only exposure is in a small outlier situated 400 yds. south of Callow Hill Camp.

Carboniferous.—The area surveyed by Mr. Whitehead includes Upper Coal Measures near Pontesford and Pontesbury. There are, however, no natural exposures, and little or no information is available concerning the small collieries that were formerly worked, chiefly for coal to smelt the lead ore of the Shelve district.

Trias.—The Lower Mottled Sandstone that rests against the north-western flank of the Wrekin is believed by Mr. Pocock to have only a narrow outcrop about half a mile wide, while the drift-covered area round Aston and Cluddley is probably underlain by the Keele Beds, and not, as shown on the Old Series map, 61 N.E., by Trias.

A small area of Pebble Beds occurs at Eyton, faulted on the east against Uriconian rocks and overlying Lower Mottled Sandstone on the west. The Lower Mottled Sandstone is well exposed in the left bank of the Severn and is seen again in Bell Brook, west of Uppington.

Superficial.—The ground between the Wrekin and Overley Hill is much obscured by loamy boulder-clay with mounds and patches of sand; while, west of Charlton Hill, the solid rocks are almost completely covered with moundy drift.

In the Severn valley three distinct terraces have been mapped at heights of about 10, 20, and 45 ft. above the alluvium.

Brown boulder-clay covers much of the country surveyed by Mr. Whitehead. On the watershed between the Severn and Teme drainages, near Gatten, the drift reaches a height of over 1,100 ft. The stones in the boulder-clay are chiefly such as might have been derived from the Stiper Quartzite ridge or the area immediately to the west of it; except that, east of the Habberley valley, fragments of Longmyndian grit and of dolerites like the intrusions of Pontesford Hill are present.

South Wales

In continuation of the revision in progress in the South Wales Coalfield Dr. Robertson has been engaged in the Merthyr Tydfil

[1] Watts, W. W., *Proc. Geol. Assoc.*, vol. xxxvi, 1925, pp. 340, 343.

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district (Sheet 231). As the memoir on that area is out of print the opportunity is being taken to bring the account of the geology up to date, especially as regards the Carboniferous rocks, which occupy about two-thirds of the district and include some 70 square miles of the northern portion of the coalfield. The remainder consists of Old Red Sandstone and provides not only delightful mountain-scenery but also an abundant water-supply, of which the larger towns farther south, including Cardiff, take full advantage.

Re-examination of the Carboniferous Limestone in the light of the Avonian sequence has revealed some interesting points regarding the westward development of the intra-Avonian unconformity. The progressive mining districts of Merthyr Tydfil, Aberdare, the Vale of Neath, the Dulais valley, and the higher portion of the Swansea valley illustrate the transition westward from steam coal to anthracite, a problem to which it is hoped to devote some further attention from the geological point of view.

T. C. CANTRILL.

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3. YORKSHIRE DISTRICT

Headquarters : York

C. E. N. BROMEHEAD, B.A., District Geologist.
G. V. WILSON, B.Sc. } Senior Geologists.
D. A. WRAY, PH.D., M.Sc. }
J. V. STEPHENS, B.Sc., B. ENG. } Geologists.
WILFRID EDWARDS, M.A. }

OWING to the absence for three months of two members of the staff, Messrs. Stephens and Edwards, in Orkney and the preparation of the memoir on the Huddersfield Sheet, progress with the resurvey of the Glossop Sheet (86) has been slow. The ground was allotted as in the previous year.[1] Mr. Edwards was mainly concerned with the Kinderscout Grits and the beds below them. He finds that the thickness of these grits north of Longdendale is about 550 ft., including three to five shale partings. The ground is much more faulted than was indicated on the original survey ; a north and south line of anticlinal folding along the Tame valley from Saddleworth to Mossley (the ' Pennine Anticline ') has been examined but not yet completely mapped. East of the fold the faults follow two dominant directions, north-north-west and north-north-east, but east of a line from Middle Edge Moss to Rhodeswood Reservoir the faulting is somewhat less, the trends become north-west and north-east and some east and west faults appear.

In the country around Glossop the most remarkable feature discovered by Mr. Stephens is the paucity of sandstones in the Middle Grits ; at Chunal, 1½ miles south of Glossop, the Huddersfield White Rock is represented by 40 ft. of sandstone and grit, but beneath this the three marine bands characterised by mut. α, β and γ of *Reticuloceras reticulatum* Bisat have all been detected and are separated by only 160 ft. of shale with no sandy beds.

A confusing area between Meltham and Holmfirth has been approached from various sides by Mr. Bromehead, Dr. Wray and Mr. Edwards. There appear to be unusual developments of ganister, coal and sandstones in the Middle Grits : Dr. Wray notes that on the horizon of the Beacon Hill Flags a bed of ganister up to 12 ft. thick is being worked at Royd Edge and Banister Edge, Meltham. It immediately overlies a 9-in. seam of coal locally known as the Lower Meltham Coal, while in the shales above it there occurs a marine band with *Reticuloceras reticulatum* mut. γ Bisat. Above

[1] ' Summary of Progress ' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 46, 47.

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this band is a representative of the White Rock with the usual ganister and coal at the top. Mr. Bromehead finds the *cancellatum* marine band about 20 ft. above this, as usual, but it is succeeded, between Harden and Wolfstones, by a sandstone unrepresented in other parts of the district, which also has a ganister top with a coal and is separated by shales from the overlying Rough Rock. This new sandstone was called " Bed A " by Green,[1] and the coal above it he termed the Upper Meltham Coal. There were thus two names, Upper and Lower Meltham Coals, for three seams, of which the middle one has been given either name.

The Rough Rock, which makes a broad spread on Honley Moors, is of a very variable nature in Honley Wood; it consists of alternations of flags and coarse massive grit. In this area the flag horizon is by no means confined to the base of the series and it is impossible to draw a definite line between it and the Rough Rock proper. Around Holmfirth and Hepworth no flags have been distinguished.

The lower part of the Lower Coal Measures is similar to that found in the Huddersfield Sheet; the marine band above the thin coal at the base is exposed near Hepworth, and Mr. Wilson finds that excellent exposures are to be seen on both sides of the Little Don River half a mile below Langsett, and also in the cutting on the old railway belonging to Sheffield Corporation a few yards north of where it crosses the road about a quarter of a mile east of Langsett; the bed is about 1 ft. thick and highly fossiliferous.

To the south of Skelmanthorpe the Better Bed Coal is absent, being represented by a fireclay only, but the Penistone Flags with some unimportant seams of coal make their appearance and have been mapped through Cumberworth and Ingbirchworth to the Penistone neighbourhood. The Whinmoor Coal, usually in three beds, now becomes important and may be the equivalent of the Beeston, but the correlation of this and the several coals in the Middle Coal Measures, as found in the country between Denby Dale, Clayton West and High Hoyland, with those of the ground already mapped to the north, is attended with considerable difficulty. At the time of the previous survey little was known of this area as, owing to the relative thinness and poorness of the seams, it had not been developed; Green dismissed it as ' obscure ' but tentatively correlated a thin coal locally known as the Clayton Common Coal with the Blocking Bed Coal of the country to the north and with the Silkstone of the south (*op.cit.*, p. 281). Recent developments in this area suggest to Dr. Wray that the Clayton Common Coal is more strictly correlative with the Wheatley Lime Coal and that a thin unnamed seam represents the Blocking Bed. The difficulty that attends any effort to correlate the succession of this with adjoining areas arises from the fact that the whole of the seams between the Silkstone and the Parkgate fall off in quality and the general succession changes much in character. Whatever the

[1] ' Geology of the Yorkshire Coalfield ' (*Mem. Geol. Surv.*), 1879, pp. 56, 57.

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conditions may have been which produced this change, they were repeated during the formation of each one of the coal seams. Dr. Wray discussed the changes in the Barnsley Bed, which crops a few miles farther east, in last year's *Summary of Progress*,[1] and as facts accumulate he may be led to a satisfactory explanation: the line of change is of great importance, as it forms the boundary between the West Yorkshire and the South Yorkshire coal districts. The structure is also in need of elucidation: from Denby Dale to Scissett the Whinmoor Coal outcrops near the bottom of the valley, but a coal near the top of the hill on the south, some 250 ft. higher, was also called the Whinmoor on the original survey and shown as surrounded by a triangle of faults; the succession is, however, normal and unfaulted, the upper seam being probably the Parkgate, while representatives of the Wheatley Lime or Silkstone Four Foot and of the Blocking Bed or Silkstone have both been worked recently between it and the Whinmoor. It is clear that in this region there will be considerable alterations in the mapping; unfortunately it is certain that the Silkstone Coal is absent in some areas and the boundary between Middle and Lower Coal Measures will there be a hypothetical line.

Mr. Wilson has continued to watch developments in the Concealed Coalfield; much of his work will be found in Appendices VII & VIII in Part II. An important item has been the examination of the fresh water mollusca, collected from the bore at Wressell by Mr. Manson in 1914, by Dr. A. E. Trueman. He reports that the types are such as are usually found in the measures that occur above the Barnsley Bed. This result is most interesting in its relation to the northern margin of the Yorkshire Coalfield, as it shows that the beds there are well up in the Middle Coal Measures and not Lower Coal Measures as was formerly thought to be the case.

Through the courtesy of the engineer in charge, important cuttings on the London, Midland and Scottish Railway in Derbyshire (see Appendix VI, Part II) and Yorkshire have been examined. At Sandal an interesting exposure of a marine bed in the Middle Coal Measures was noted at a point about 100 yds. south-west of Two Lands Bridge, which crosses the railway about 1¾ miles north-east of Sandal and Walton Station. This section of the line has recently been widened, and the cutting has been earthed over again. The structure of the ground is much obscured by faulting, and the relations of the marine bed to the surrounding rocks are difficult to make out. The section showed a variable bed of limy cank up to 9in. thick resting on a 3-in. coal and overlain by fissile, very rotten shales, which yielded *Orbiculoidea* and fragments of *Pterinopecten*. In many ways the section is similar to that seen in Cudworth Brick Yard, where a bed which is supposed to be the Mansfield Marine Bed is exposed.[2] The marine bed there lies above the Oaks Rock of that district. As far as can be made out the exposure in the rail-

[1] Appendix VI, pp. 127–37.
[2] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 62.

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way cutting lies on the downthrow side of a fault, which runs parallel to and directly along the course of the line. Across the fault the base of the Oaks Rock is seen, so it is evident that the marine bed lies above that rock, and it seems highly probable that it is the Mansfield.

The number of enquiries on water-supply and other matters continues to increase, and we are indebted to several boring firms and to Professor P. F. Kendall for a great number of records of bores. For Derbyshire Mr. Stephens is preparing a Water-Supply Memoir which is nearing completion.

C. N. BROMEHEAD.

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4. LANCASHIRE DISTRICT

Headquarters: Manchester

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W. LLOYD, B.Sc.
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} Geologists.

IN the Manchester area, Sheet 85, progress has been slow owing to the absence throughout the year through illness of one member of the staff, and the detailing of a second, Mr. Jones, for four months work in the Orkney Islands. Some heavy work on the examination of underground tunnels has been undertaken by Mr. Tonks. Mr. Wright has been engaged in a study of the fossil remains obtained from these tunnel sections and from the limited surface exposures, but the results are not yet available for publication. The re-surveying of Sheet 85 having been completed the six-inch maps of the area are being produced, while a start has been made on Sheet 84 (Wigan).

In the *Summary of Progress* for 1925 mention was made of the rapid variation of the lower beds of the Middle Coal Measures across the line of the Irwell Valley Fault. Dr. Sherlock has found an instance of similar variation in the metals above the Rams Mine in the area between Little Lever and Radcliffe on the north, and Swinton on the south, and has been able to show that the line of this great fault does not in this instance, directly at any rate, control the variations in the strata.

In the Little Lever and Radcliffe district the Three Yards Mine is a well-known seam, but south of the Irwell Valley Fault the coal is not recognised. Instead we find a group of coals—the Shuttle, Crumbouke, Ockley, and Brassey or Little Mines.

In the northern area the Three Yards is represented at Kennel Pit, in the west of Radcliffe, by two seams separated by 2¾ ft. of 'bin.' At Allen's Green Colliery the Three Yards is much the same, but there also appear three coals separated from one another by fireclays and from the Three Yards below by about 40 ft. of strata. These three nameless coals appear to represent the Crumbouke, Shuttle, and Ockley of the southern area. In Radcliffe, south of the Irwell, the Spring Well Pit showed the Three Yards as before with the three coals above separated from it by 28 ft. of strata. At Meadow Pit, Stand Lane Colliery, the three new seams are separated from the Three Yards by only 1¾ ft. of fireclay, and the name Three Yards was given to the whole group.

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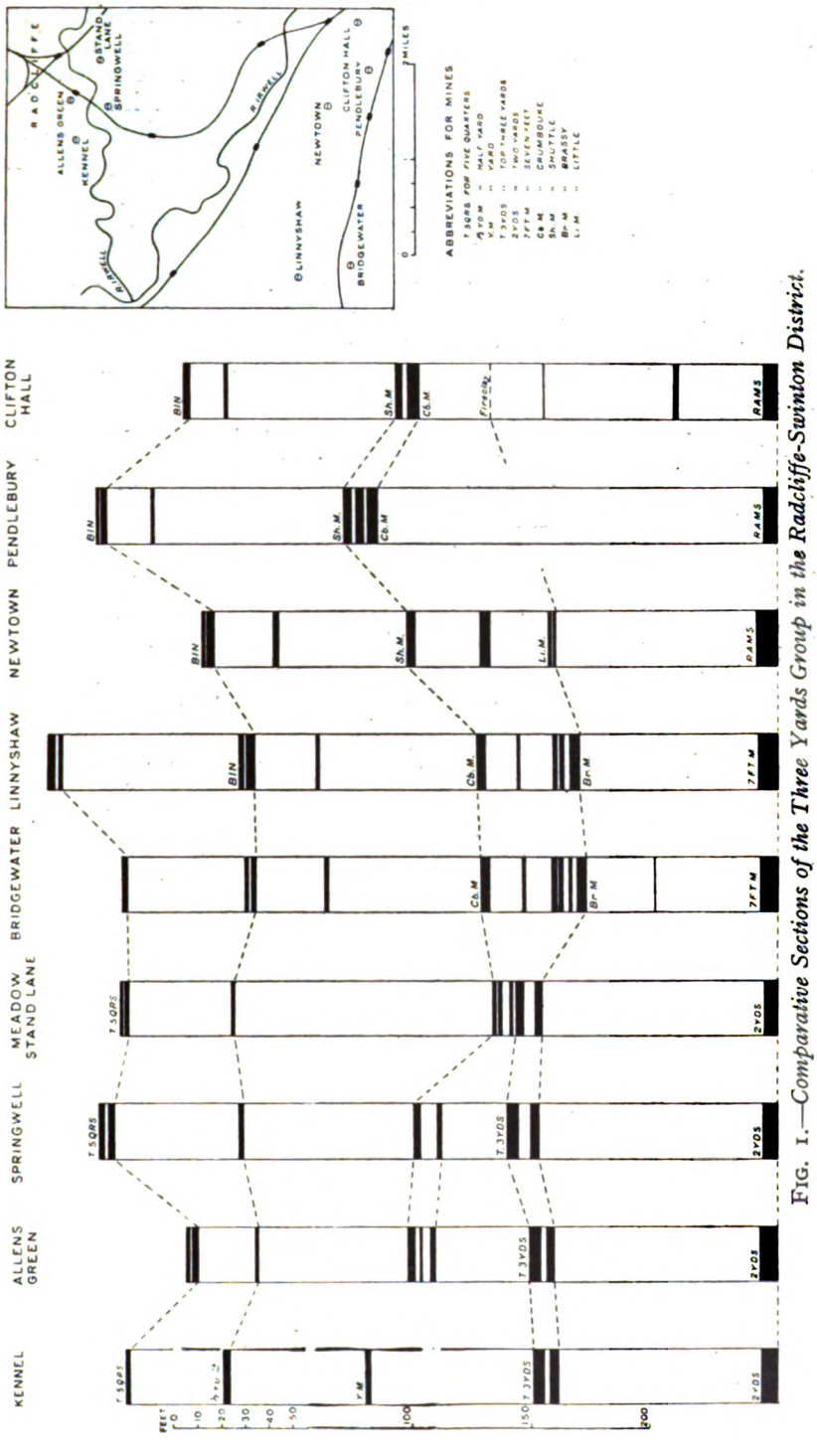

FIG. 1.—*Comparative Sections of the Three Yards Group in the Radcliffe-Swinton District.*

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In the southern area we find a group of coals at Bridgewater and Linnyshaw collieries, Walkden, similar to that at Stand Lane. The top member is here named the Crumbouke and the bottom one the Brassey, while the name Ockley is given to an intermediate coal. At Newtown Colliery there is a top seam, the Shuttle, corresponding to the Crumbouke of Bridgewater, and midway between the two is the Four Feet Mine. At Pendlebury Colliery there are three coals, the top one called the Shuttle and the bottom one the Crumbouke, with only about 2 ft. of strata between each coal and the next. Finally, at Clifton Hall Colliery the group of coals is condensed into two seams, the Shuttle above and the Crumbouke below, with only a fireclay between them.

It appears that the Three Yards of the northern area is represented by the Brassey (Little) Mine of the southern area and that at Pendlebury this has disappeared altogether, while at Clifton Hall it may be represented by a fireclay 28 ft. below the Crumbouke.

In one-inch Sheet 84 (Wigan) a small area has been surveyed by Mr. Tonks around Ormskirk. Over most of this area the surface is boulder-clay and Shirdley Hill Sand. The boulder-clay gives rise to heavy clay and sandy clay soils with stones. In a few places the clay soils are so heavy that they are left as permanent pasture; but on the rising ground, downwash, and a thin cover of Shirdley Hill Sand mix with the boulder-clay to give lighter soils.

Mapping has also been commenced by Mr. Jones on Sheet 84 to the south and east of Horwich, where a considerable area is covered by Lower Coal Measures. These are much faulted and are obscured by drift in the lower ground. Little mining has been done, and the measures for the most part appear to be barren, except for the Upper Mountain Mine, which has been worked in a small area about Green Hill.

W. B. WRIGHT.

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5. CUMBERLAND DISTRICT

Headquarters: Whitehaven

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E. E. L. DIXON, A.R.C.Sc., B.Sc.
T. EASTWOOD, A.R.C.Sc. } Senior Geologists.
F. M. TROTTER, M.Sc.
S. E. HOLLINGWORTH, M.A., B.Sc. } Geologists.

IN Cumberland the mapping of the six-inch sheets covering Sheet 18 (Brampton) has been completed:—by Mr. Trotter in the area north-east of Carlisle, and by Mr. Hollingworth on the borders of Northumberland west of Alston. Apart from brief visits to the field the other officers have been chiefly engaged in the production of maps and memoirs. Several shafts and bores for coal or haematite have been examined and many old records obtained. Mr. Eastwood took part in a conference of agricultural research workers held in September at Wykeham near Scarborough.

In November the office was closed and staff and stores transferred to Headquarters in London.

BRAMPTON SHEET

Mr. Trotter finds that an outcrop of the widespread Carboniferous rocks of the Bewcastle Sheet (12) protrudes into the New Red rocks of the Brampton district (Sheet 18) east of Hethersgill, where it forms a triangular area with its apex pointing south in the neighbourhood of Walton Moss. On the east the rocks are bounded by a post-Triassic fault (the Crosby Fault), whilst on the west they are succeeded by unconformable New Red rocks, the junction being exposed in a section in the Hether Burn, about 1 mile east of Hethersgill. These rocks are considered to belong to the Fell Sandstone Group.

Farther north-west, to the east of the faulted junction with New Red rocks at Brackenhill on the River Lyne (Sheet 12, 1½ miles north-north-east of Kirklinton) exposures of sandstones, shales and thin marine limestones probably represent the upper part of the Fell Sandstone Group. One bed of sandstone is at least 200 ft. in thickness.

Mr. Hollingworth has completed the survey of a tract of Lower Carboniferous rocks just beyond the southern margin of Sheet 18.

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Here the beds lie wholly within the Middle and Upper Limestone Groups. Good sections of the Scar Limestone and overlying beds are exposed in Gilderdale (Sheet 24), where the top of this limestone is characterised by a bed rich in pyrites. This feature appears at the same horizon in Knar Burn farther north (Sheet 18). Beds above the Little Limestone are well exposed at the head of Croglin Water (Sheet 24). The Pattinson Sill here extends downwards to within a few feet of the Little Limestone, and the overlying Firestone Sill is comparatively thin.

In Gilderdale the Whin Sill is over 80 ft. in thickness, and in places its central parts are characterised by an exceptionally coarse texture.

A new conception of the structure of the New Red Sandstone Series of the north-western and western parts of the district has been acquired by Mr. Trotter. The main feature is the repetition of the sequence—St. Bees Shales, St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales—by a fault (the Crosby Fault) trending from the eastern side of Carlisle, by Low Crosby on the Eden, to the River Cambeck east of Walton Moss. Throwing down south-eastward, it has the effect of shifting the outcrops of the beds south-westward upon its north-westward side. The key to this structure is furnished by two sections; the one in the Hether Burn, the other in the Cambeck south-east of the fault.

In the Hether Burn, commencing about 1 mile east of Hethersgill, the St. Bees Shales, resting unconformably upon Carboniferous rocks, are succeeded westwards, and downstream, by St. Bees Sandstone, Kirklinton Sandstone and Stanwix Shales, the base of the latter being exposed near East Cliff where the Hether Burn joins the Lyne. The Carboniferous Rocks (which occur in the above-mentioned triangular area) extend from the Hether Burn apparently to within a quarter of a mile of the Cambeck (i.e. about 2¼ miles east-south-east of Hethersgill) where a section of boulder-clay is composed—matrix and boulders alike— entirely of Carboniferous debris: suggesting that the solid rocks occur *in situ* at this locality but are separated by a fault from the New Red rocks exposed in the Cambeck close at hand.

To the south-east of the fault, in this neighbourhood, the Cambeck flows in Kirklinton Sandstone, which succeeds the St. Bees Sandstone in a westerly direction about half a mile north of Walton, the beds striking against the fault. South-westward the Stanwix Shales apparently occur at High and Low Crosby east-south-east of the fault, being thus separated from the main outcrop north of Carlisle. North-eastward along the Cambeck and one of the tributaries of the Irthing farther east the St. Bees Sandstone is underlain by St. Bees Shales which rest unconformably upon the Lower Carboniferous rocks of the mair area east of Brampton.

Thus the effect of the Crosby Fault is to shift the unconformable junction of the New Red with the Carboniferous rocks about 3

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miles westward. As one approaches Carlisle the throw of the fault is somewhat less.

Whitehaven Sheet

Additional mining information has been collected from this area; and further points relating to the succession in the Skiddaw Slates have been cleared up by Messrs. Dixon and Hollingworth.

Mr. Dixon has studied a phase of the local glacial retreat near Floutern Tarn north of Ennerdale (Sheet 29) just beyond the eastern margin of the district. Detailed examination of the phenomena occurring farther south has shown that, for a considerable time after the high ground south of Ennerdale was vacated, there still proceeded from the valley a strong flow of ice which united with the southward-moving ice on the lower land west of the hills. Mr. Hollingworth has traced a series of stages in the withdrawal of the ice south of Ennerdale: these, as a group, are of earlier date than the formation of Glacier Lake Ennerdale.

Maryport Sheet

Borings put down for the Birkby Colliery, in the area bounded by the River Ellen and the Maryport and Rosegill Faults, have been examined by Mr. Eastwood. Although the upper part of the Productive Measures has been removed by denudation, the lower coals, including those worked both at the present and old collieries, occur in workable thickness.

Some time was spent by Mr. Eastwood in tracing, eastward from Cockermouth, the basaltic lavas [1] and underlying conglomerate to their termination near Bothel (Sheet 23). These lavas are now definitely considered to be of Carboniferous age. Their occurrence is of extreme interest, as it is accompanied by a series of peculiar coincidences which have conspired hitherto to disguise their true position in the geological sequence; for example (1) they occur only upon this north-western border of the Lake District; (2) their horizon is at the very base of the Limestone Series of West Cumberland; (3) their position, between the top of the Skiddaw Slates and the Limestone Series, is occupied elsewhere on the northern outcrop by the Ordovician Borrowdale lavas, which are here denuded away; (4) the eastern end of their outcrop is in contact with, and almost in line with, the western end of the outcrop of the Borrowdale lavas, the latter being apparently succeeded by the Carboniferous Limestone with basal conglomerate.

Bernard Smith.

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv*), 1927, p. 53.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters: Newcastle-on-Tyne

R. G. CARRUTHERS, District Geologist.
G. A. BURNETT, B.Sc.
A. FOWLER, M.A., B.Sc. } Geologists.
W. ANDERSON, M.Sc.

IN Northumberland most of the field-work during the past season lay in Sheet 5 (Cheviots), the survey of which was completed. Mr. Burnett revised the ground round the upper reaches of the Coquet, while Mr. Anderson undertook strips along the southern edge of the map round the Border and near Alwinton. Mr. Fowler was largely occupied in going over Coal Measure and Limestone area in Sheet 9, revised by the late Mr. Maden in 1926, and of which a thorough knowledge is required before the memoir can be written.

Silurian.—The patch of greyish-green shales and greywackes, seen along the Border near the southern margin of Sheet 5, is assigned to the ' Upper Silurian ' (probably Wenlock) on the published map. As no fossils have yet been discovered in these beds, their precise age still remains doubtful. They are steeply inclined and highly folded. Good exposures are seen round the headwaters of the Coquet above Makendon, but junctions with the overlying volcanics are hidden.

Cheviot Lavas and Granite.—The lavas and ashes along the southern edges of the Cheviot massif are the lowest known on the English side of the Border, but the coarse biotite ashes, with which the eruptive series begins near the ' Silurian ' inlier, can only be regarded as a local base, for they contain blocks of a lava no longer seen *in situ*. Fragmentary exposures of conglomerate beneath this series suggest that the earliest Old Red rocks hereabouts are of a sedimentary nature.

The first lavas seen are andesites, notably rich in biotite, and with much ash incorporated in the lower flows; at a higher level, interbedded ash recurs, accompanied by bands of pitchstone, well seen in the Coquet at Blindburn. Andesites of the normal Cheviot type are found above this series; towards Windyhaugh they sometimes show large inclusions of ' Silurian ' shale and one or two flows are of a semi-vitreous character.

Around Carshope and Rowhope several ' shatter-belts ' have been noted, all trending N.E.; they are up to 75 yards wide, with quartz and calcite cementing the brecciated fragments.

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Granite and Dykes.—As no actual junctions have been found, it is not known whether the southern margin of the Cheviot granite boss shows the close interweaving with the lavas that is seen along the northern edges. It may be noted, however, that the marginal portion to a distance of half a mile from the lavas, is fine-grained and more basic than usual.

Along the Breamish valley, between Linhope and High Bleakhope, many new dykes have been mapped and their radial distribution from the granite boss is now more apparent. A petrographic examination of lavas and granite near their junction round High Bleakhope shows much contamination of both rocks, and recent field-work further down the valley, towards Linhope, suggests that similar phenomena also prevail there. Contact alterations by the dykes are slight, save in a narrow strip of lavas separating two large intrusions at the mouth of the Linhope Burn.

Cementstone Group.—The conglomerate outlier of Windy Gyle, seen well within the lava massif, on the Border, is comparable with the Roddam Dene Conglomerates near Wooler, and as such, should be regarded as a local Carboniferous basement bed. The Cementstone rocks seen along the southern fringe of the lavas are, on the other hand, of normal type. Notwithstanding their pronounced overlap on to older rocks, extending even to the 'Silurian,' only a few feet of the very lowest beds show any traces of conglomerate. On the S. bank of the Coquet, below Alwinton there is a notable cliff section of horizontal Cementstone strata quite 150 ft. high.

Bernician.—The presence of Scremerston measures south of the Simonside Fells has been confirmed by the discovery of a rich entomostracan shale in the stream 700 yds. E. of Selby's Cove. In the Limestone Group new drifts have lately been driven in the coal under the Great Limestone at Wards Hill, 3½ m. S.S.E. from Rothbury: the seam here is thicker than usual, averaging 31 inches, with a roof of hard limy shale rich in marine fossils. Small marine fossils have also been noted above the Chirm seam. In the Stanton district a good outcrop of the Parrot Coal (at one time much wrought hereabouts) have been noted on the left bank of the Font, S.W. of Maiden Hall: it was 29 inches thick, with several thin seams of parrot interleaved.

Coal Measures.—Mr. Fowler reports that mining operations have been resumed S. of Pegswood Moor, and several drifts opened up along the How Burn. The Little and the Old Man coals are being wrought here: they are only 6 ft. apart, and are low in the series, being about 20 fathoms above the Bessie Grey or Brockwell Coal. A *Carbonicola* band, 65 fathoms above the Yard Coal, has been noted on the coast near Cresswell Farm 500 yds. S.W. of Snab Point: this had previously been found in neighbouring borings.

Much new mining information has been collected in the areas N. of Morpeth, and is now being utilised to complete the field evidence previously obtained.

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Glacial.—There is a thin but widespread covering of purplish boulder-clay south of the Cheviot, derived from the underlying lavas: occasionally the colour changes to bluish-grey owing to a local predominance of 'Silurian' material. Mr. J. A. Smythe[1] had reason to believe that at the maximum period of glaciation the Cheviot ice-sheet was over-ridden and pushed back into the hills by the Western ice. Confirmation of this is seen, along the edge of the lava area, in the valley half a mile below Hazeltonrig, where 25 ft. of grey boulder-clay, packed with Cementstone debris, covers the purplish-red Cheviot clay quite distinctly. 'Retreat phenomena,' attending the final phases of glaciation, are not common well within the Cheviot hill-group, but are very evident on the lower ground around Hazeltonrig. The southern spur of Northfieldhead Hill is crossed by a descending series of small notches, 15 in all, while there are still more on Harden Hill and Ewe Hill, ranging from 5 to 40 ft. in depth.[2] The most striking of all is fully a mile long, and at its maximum is about 100 ft. deep; this channel starts on the hillside S. of Hazeltonrig, and, running N.E. crosses the Shartley Burn almost at right angles. All these channels must have been due to the presence of stagnant 'Western ice' over the lower ground, at a time when the smaller Cheviot sheet had disappeared.

R. G. CARRUTHERS.

[1] *Trans. Nat. Hist. Soc. Northum. and Durham*, New Series, vol. IV, p. 116, 1909–1915.
[2] First described by Smythe *loc. cit.*, pp. 108-109, Photos. 6 and 7.

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(B)—SCOTLAND

1. AYRSHIRE, DUMBARTONSHIRE AND STIRLINGSHIRE

E. B. BAILEY, M.C., B.A., District Geologist.
V. A. EYLES, B.Sc.
J. B. SIMPSON, B.Sc.
A. G. MACGREGOR, M.C., B.Sc. } Geologists.

FIELD-WORK was carried out by this unit along the borders of one-inch Sheets 8 (Carrick) and 14 (Ayr), and in one-inch Sheet 30 (Glasgow and Greenock).

AYRSHIRE

Messrs. Eyles and MacGregor revised the Old Red Sandstone outcrops that occur north of the head of the Stinchar valley, and Mr. J. E. Richey spent some time re-examining the Ordovician-Silurian areas on the margins of the Dailly coalfield.

Ordovician-Silurian.—In the Ordovician-Silurian inlier north-east of Girvan graptolites have been collected by Mr. Eckford and determined by Dr. Gertrude Elles which extend in certain particulars the work of Macconochie during the revision of the Southern Uplands. Mr. Eckford's examination was carried out in conjunction with Mr. Richey, who furnishes the following account.

Near the south-west end of the Ordovician-Silurian inlier, westwards of Trochraigue mansion-house, a thick conglomerate considered to be the Bennan Conglomerate occurs in a broad outcrop upwards of 600 yds. in width. It apparently succeeds shales exposed in a stream southwards of the mansion-house from which Macconochie collected a fauna similar to that of the Craighead (Stinchar) Limestone.[1] In an old quarry north-west of the mansion-house, from shales immediately overlying the conglomerate and lithologically resembling its matrix, Mr. Eckford has found *Dicellograptus morrisi*, which Dr. Elles[2] assigns to the Lower Hartfell (Lower Caradoc). The shales probably correspond to the Ardwell Group of Lapworth.

North of Trochraigue mansion-house, from grey shales included in a tumultuous mass of brecciated shales. Macconochie collected graptolites indicating perhaps a slightly lower horizon. These breccias have till now been taken to be the north-easterly continuation of the conglomerate.[3] Locally, however, they are traversed

[1] Peach, B. N. and J. Horne, 'The Silurian Rocks of Britain, Vol. I, Scotland' (*Mem. Geol. Surv.*), 1899, p. 505.
[2] 'Monograph of British Graptolites,' pt. x., 1914, p. 518.
[3] *Op. cit.*, p. 505.

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by abundant pink albite-quartz-veins (26303), and are also bleached and evidently contact-altered. It is noteworthy also that the breccias contain isolated pebbles of chert where they adjoin the conglomerate outcrop, from which the pebbles were presumably derived. The breccias are now concluded to lie within a volcanic vent or else to be the brecciated roof of an intrusion, and seem assignable to no earlier igneous period than that of the Lower Old Red Sandstone. They are seen to extend from a point immediately north of the old quarry referred to above for 350 yds. to the east-north-east.

A new graptolite locality has been found north of the Craighead Limestone Quarry. Grey shales associated with grey flags are exposed in a stream north-east of the road which skirts the quarry on its north-east side, and 400 yds. north-west of Craighead farm-house. They have yielded *Climacograptus antiquus*, *C. lineatus* and *Amplexograptus perexcavatus*, and are assigned by Dr. Elles to the Upper Llandeilo, either the base of the *Climacograptus peltifer* Zone or the top of the *Nematograptus gracilis* Zone. These shales therefore closely approximate in stratigraphical position to the Craighead (Stinchar) Limestone, which in the field they apparently overlie. Farther to the east-north-east, in a stream south-east of Farden and a quarter of a mile north-east of Glenlochrie, a faulted exposure of pale ochreous-weathering shales has yielded *Monograptus triangulatus* among other graptolites. The shales therefore belong to the *Monograptus gregarius* Zone and are without doubt the Glenshalloch Shales reappearing along the faulted south-east limb of the Craighead-Mulloch Hill anticline. Around the north-easterly nose of this anticline, 2 miles farther to the north-east, the main outcrop of these pale ochreous shales was mapped in the first instance by Lapworth. *Monograptus triangulatus* has not hitherto been recorded from the Glenshalloch Shales.[1]

Lower Old Red Sandstone.—The succession on broad lines is sandstone with conglomerate, followed by lavas and intrusions. The lavas are practically all olivine-basalts, often with porphyritic felspar. Acid porphyrite builds big irregular sills or laccoliths at Garleffin Fell, Lennie and Tairlaw. There are also important sills of dolerite, some of them quartz-bearing. Mr. MacGregor reports that an intrusive complex of the suite, at the Fore Burn, consists of diorite, plagiophyre and acid porphyrite, locally extremely rich in dark-bluish tourmaline. The country-rock, sediment and lava, is much altered, with the production of epidote in the basalts and some tourmaline. In the Fore Burn two narrow tourmaline-sulphide veins were found. Specimens examined by Messrs. Sutcliffe and Hallimond contain pyrites, mispickel, and possibly chalcopyrite, with traces of topaz and cassiterite; the percentage of tin, however, is less than 0.0001.

Upper Old Red Sandstone.—Mr. Eyles has found a small

[1] *Op. cit.*, p. 533.

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hitherto undetected outcrop of Upper Old Red Sandstone, including cornstone, half a mile east by south of the Pilot and immediately east of an old coach-road. It is faulted against rocks of Lower Old Red Sandstone age at the only exposed contact.

Dumbarton and Stirling

North of the Clyde Mr. Simpson commenced work at Drymen, and has surveyed a tract of country south of this locality and west of the River Endrick and Blane Water, occupied by Lower and Upper Old Red Sandstones and lavas of Calciferous Sandstone age.

Lower Old Red Sandstone.—Rocks of this age are exposed in the River Endrick at Gartness. They consist of brown and purplish-brown sandstones often with pebbles of andesite lava, and thinner beds of brown marl in which plant-impressions are not uncommon, though usually not sufficiently good to permit of identification.

Upper Old Red Sandstone.—Numerous excellent sections of this formation are exposed in the streams that rise on the northern slopes of the Kilpatrick Hills and drain into the Endrick.

Lithologically the Lower and Upper Old Red Sandstone strata are quite distinct. In its lower horizons the Upper Old Red Sandstone comprises false-bedded brick-red or orange-red strata, somewhat reminiscent of the New Red Sandstone rocks of Mauchline and elsewhere, and the resemblance is heightened by the presence of a certain number of distinctly wind-rounded grains that hint at continental if not desert conditions. Towards the top of the group the red colour gives place to yellow and cornstones appear.

Igneous.—In the Kilpatrick Hills a small area of volcanic rocks has been surveyed west of Auchineden Hill. These are for the most part basalt lavas of microporphyritic (Jedburgh) type.

The base of the group, as at present drawn, runs along the south-west edge of the large intrusion of Jedburgh basalt, lettered F on the one-inch map (Sheet 30), south of Knockvadie. Lava-flows and bedded ash have been proved to occur below this mass and to rest on sandstones of Upper Old Red type without the intervention of Cementstone strata.

Glacial.—North of the Clyde, in the original survey of the Drymen district by Jack,[1] it was noted that the boulder-clay was charged with marine shells of recent types. This boulder-clay he considered to be the ground moraine of a glacier that swept out marine deposits from the Loch Lomond basin.

Resting on the boulder-clay between Drymen and Killearn is a considerable area of sands and gravels in which, also, shells were noted, often rolled and waterworn. Jack was inclined to interpret the shell-bearing gravel as a consequence of a further submergence below sea-level, but it was pointed out by J. Geikie[2] that the

[1] Jack, R. L., 'Notes on a Till or Boulder Clay with Broken Shells in the Lower Valley of the River Endrick near Loch Lomond, and its Relation to certain other Glacial Deposits,' *Trans. Geol. Soc. Glasg.*, vol. v., part 1, 1875, pp. 5–25.

[2] Geikie, J., 'Great Ice Age,' 1894, p. 281.

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shells could easily be derived from the older shelly boulder-clay, and that their water-worn condition supported this contention. On his view the sands and gravels were a fresh-water lake deposit.

In the memoir on the Glasgow district, Bailey [1] drew attention to a channel near Balfron eroded by the eastwardly escaping waters of Geikie's lake, and interpreted this lake as temporarily impounded by retreating Loch Lomond ice.

In the course of the year's work further evidence bearing on this problem has been collected. A widespread expanse of sand and gravel extends south from Finnich Drummond to High Finnich, and terminates in a well-marked moraine ridge, which, so far, has been traced 2 miles westwards from near the volcanic neck of Meikle Caldon to Cameron Muir. It is known to extend still further. It lobes outwards to the south and there is no doubt that it has been deposited by ice from the north.

The shelly boulder-clay is found to extend over a much wider area than was indicated in the original map, and in particular is proved to exist close to the moraine on its northern side at a height of 300 ft. on the banks of Finnich Glen west of Auchineck House. So far no shells have been noted in the boulder-clay south of the moraine.

It is believed that we are here dealing with the frontal moraine of the Loch Lomond glacier that deposited the shelly boulder-clay.

E. B. BAILEY.

[1] Bailey, E. B., 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), 2nd Ed., 1925, p. 230.

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2. PEEBLESSHIRE AND MIDLOTHIAN

J. E. Richey, M.C., B.A., District Geologist.
H. H. Read, D.Sc., A.R.C.Sc., Senior Geologist.
J. Phemister, M.A., B.Sc., Geologist.

ONLY a small area in one-inch Sheet 24 was mapped during the past year owing to the surveyors concerned being engaged in memoir writing and other work, and about 35 square miles of post-Silurian rocks have still to be revised before the Sheet can be colour-printed.

Carboniferous Limestone Series.—Certain advances have been made in the detailed stratigraphy of the lower part of the Carboniferous Limestone Series in the Carlops-Leadburn district, which forms the southern portion of the Midlothian coalfield. The Lower Limestone sequence of the Carlops area was dealt with in a recent *Summary of Progress*,[1] and the individual limestones were correlated with those in the well-known succession established in the Bilston Burn to the north. Near Leadburn, $4\frac{3}{4}$ miles east of Carlops, exposures are few, but the continuation of the various limestones into this area is proved by a diamond bore at Hall Farm, which was examined by the late Dr. C. T. Clough. In this boring the succession is as follows :—

	Ft.	In.
Harelaw Limestone	1	7
Strata including two thin coals	32	—
Bilston Burn Limestone	27	—
Strata	20	—
(? Upper) Vexhim Limestone	—	9
Strata	41	
North Greens Limestone	64	—
Strata	39	—
Gilmerton Limestone { Limy shale	18	—
Gilmerton Limestone { Limestone	35	—
Strata	10	—
Limestone	4	6
Strata	38	—
First Abden Limestone { Limestone	1	6
First Abden Limestone { Limy shale	3	—
Strata	11	—
Cephalopod Limestone, and limy shale	12	—

In this succession the Lower Vexhim Limestone is apparently unrepresented, the strata between the North Greens Limestone and the limestone correlated with the Upper Vexhim being mainly sandstone. A few miles east of Leadburn, in Sheet 24, the Lower Limestones occur near Hillhead and Side in outcrops which extend

[1] Richey, J. E., *in* 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, pp. 110–112.

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northwards into Sheet 32, along the eastern margin of the Midlothian Basin. The sequence of limestones has been worked out from exposures at North Middleton, Esperston, and Rosebery Reservoir (South Esk),[1] and resembles that proved at Leadburn sufficiently closely to enable the following correlations to be made :—

Hall Farm Bore, Leadburn (one-inch Sheet 24)	*Esperston-Middleton District* (one-inch Sheet 32)
Harelaw Limestone	Thin limestone, South Esk
Bilston Burn Limestone	Thick Esperston Limestone
(? Upper) Vexhim Limestone	Thin limestone with Cauda-galli
North Greens Limestone	Thick limestone of Middleton Quarries
Gilmerton Limestone	Thick limestone of quarry south-west of Wester Middleton
? First Abden Limestone	Thin limestone in burn at North Middleton

The limestones of the Esperston-Middleton succession have already been recorded in the Edinburgh District Memoir,[2] with the exception of the thin post at the base. This was recently identified in the Middleton North Burn, a little way downstream from the bridge at North Middleton, where it outcrops from beneath sandstone and shales containing ironstone nodules. A gap of several yards separates these strata from an overlying thick limestone resting on a coal-seam. This thick limestone represents either the Gilmerton Limestone or the North Greens (Middleton Quarry) Limestone ; if the latter, the Gilmerton Limestone must be cut out of the section by a fault.

J. E. RICHEY.

[1] Hinxman, L. W., and C. B. Crampton, *in* ' The Geology of the Neighbourhood of Edinburgh ' (*Mem. Geol. Surv.*), 1910, pp. 186–190.
[2] *Loc. cit.*

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3. FIFE AND KINROSS

C. H. DINHAM, B.A., District Geologist.
D. HALDANE, B.Sc.
J. K. ALLAN, M.A., B.Sc.
J. KNOX, B.Sc.
} Geologists.

DURING the past year, owing to exigencies of other work, Mr. Allan alone of this unit has been continuously engaged in the resurvey of the Fifeshire coalfield, Mr. Knox joining him in field-work for a few weeks in the autumn. The whole coal-bearing area, from the western boundary of Fife to the great dislocation which truncates the Dysart coalfield near Markinch, has now been revised, and only a small tract of Calciferous lavas and sediments still remains to be mapped. With the generous assistance of the various colliery companies, much further mining information has been secured by all members of the unit; some important deep bores in progress have also been examined.

Limestone Coal Group.—On the north shore of Loch Fitty, about 130 yds. east from the western boat-house, a low cliff section reveals several feet of shales (fakes and blaes) containing lamellibranchs and other marine fossils. As a result of Mr. Allan's work it may now be safely assumed that we have here an exposure—at present the only known natural exposure—of the shelly marine horizon which rests on the Stink or Sulphur Coal of the Dunfermline district and on the Smithy Coal of Bo'ness.[1] The same strata have been found to be fossiliferous in cross-cut mines and in bores; the horizon is probably persistent through western and west-central Fife, but it is not as yet possible to affirm its presence outside this tract. In this connection it should be remarked that in the Valleyfield area, where this group reaches its maximum thickness, one or two other neighbouring 'shelly' horizons are recorded, both above and below the marine band here considered; generally these contain nothing more marine than *Lingula*, but they may be expected locally to yield other brachiopods or even encrinites, as at Carriden in the Bo'ness field.[2] One of the *Lingula* bands lies a few feet above the Dunfermline Splint Coal, and may possibly correspond to that found on top of the Milton Grove or Lower Knott Coal in the Stirling district.

A further step in correlation between Fife and the Central

[1] *Cf.* Cadell, H. M., 'A Volcano in the Bathgate Coalfield of West Lothian,' *Trans. Inst. Min. Eng.*, vol. lxv, pt. 5, 1923, p. 257.
[2] 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, p. 118, fig. 11, col. (1).

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Coalfield has resulted during the year from the examination of bore cores by Mr. Haldane and Mr. Manson. The marine band in the 'Black Metals' has in recent years been traced all over the Central Coalfield [1] from Glasgow and Lesmahagow to the vicinity of Stirling; the Kilsyth Coking Coal (equivalent to the Milton Grove just mentioned) and a few other associated but rarely workable seams lie below it, but most of the valuable coals of the group are found above it. It has not hitherto been traced on the north side of the Forth, but we now know that it is to be expected at least as far east as Culross and perhaps Saline. In this part of Fifeshire, below the Main or Lower Four Foot of Comrie (Jewel or Swallowdrum of Valleyfield and Lochgelly Splint of Blairhall), lies a zone, about 250 ft. thick, which is generally barren of even the thinnest coal seam, but commonly contains two fairly thick horizons of shales (blaes) and ironstone ribs, alternating with thick sandstones. The upper and thinner of these blaes beds has yielded Productids and other marine fossils, the lower mostly *Lingula* and entomostraca, and there is no doubt that together they represent the 'Black Metals' of the west. It follows that the Glassee, Mynheer, Five Foot, and Splint coals of Dunfermline and eastern Fife form a group that is represented in the Central Coalfield only by the Kilsyth Coking Coal and adjacent seams—a conclusion long previously suspected, but now receiving important confirmation. There appears to be some indication that east of the Culross and Saline area this marine horizon may cease to carry fossils, but it is difficult to be certain until the Survey have the opportunity of examining a section through these strata in Central Fife. Whether, in the type area at Lochgelly, the Lochgelly Splint and Parrot Coals lie above or below this horizon has not been definitely proved, but from the evidence available it is believed that they overlie it.

In the ground between Dunfermline and Blairenbathie Mr. Allan found that intense N.N.E. folding, with powerful cross-faulting, is still the dominant structure. Correlation of individual coals of the thick but variable Jersey and Fourteen Foot groups is still a matter of the greatest difficulty, and is further complicated by the intrusive dolerite sill occurring about this level. This sill thickens considerably to the north, and Mr. Allan finds reason to suppose that its source lies in that direction, towards the continuation of the great Ochil Fault, which in some other parts of its course appears to have acted as a conduit for the dolerite magma.[2]

Upper Limestone Group.—The Index Limestone at the base of this group has been further traced in the ground revised by Mr. Allan, but no additional light has been shed on the presence or position of the higher limestones.

In this connection it is worthy of remark that the Lyoncross

[1] *Ibid.*, pp. 110–12.
[2] Haldane, D., in 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, Appendix VIII.

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Limestone of the Central Coalfield—the thinnest limestone of the group—is not known to extend east of Blairhall and Comrie, and even there it is developed merely as a thin bed of blaes, with scarce marine fossils: in eastern Fife it is perhaps entirely unrepresented. It can, however, now be shown that its position lies a few fathoms above the Crumpy or Upper Coal of Inzievar, and that this seam is thus equivalent to the Quarry Coal of Plean and Denny (Stirlingshire), while Cadell's Parrot of the former area is not far from the position of the Chapelgreen Coal of Kilsyth.

A special study was made by Mr. Allan of the region west of Kinglassie, resulting in considerable alterations to the mapping of the Upper Limestone Group. The limestone hitherto correlated with the Castlecary is now regarded as the Calmy, and the upper limit of the group is drawn about 30 fms. higher.

Millstone Grit and Coal Measures.—In the same area Mr. Allan found that the Millstone Grit cannot exceed 65 fms. in thickness and is more probably only 35 fms. It is succeeded by Coal Measures, of which about 150 fms. have survived denudation. The lowest coal, about 15 ft. below the Westfield Shale, marks the beginning of an extraordinary deposition of organic matter, attaining at the maximum a thickness of no less than 130 ft. in a total of 200 ft. of strata. No correlation of this remarkable sequence with the standard sections of Dysart and Leven is yet possible.

In the last-mentioned field, Mr. Knox has found that the normal easterly dip is broken by two major folds, with axes running N. and S.—a syncline in the west and an anticline in the east—which extend northwards to the great boundary fault, but pitch out southwards before reaching the coast, where the dip is constantly to E. We seem in these to have reached the eastern limit of that belt of repeated N.N.E.—S.S.W. folding whose other border lies near Culross, Blairhall, and Saline, 18 miles to westward.

C. H. DINHAM.

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4. NORTH HIGHLANDS

J. E. RICHEY, M.C., B.A., District Geologist.
H. H. READ, D.Sc., A.R.C.Sc., Senior Geologist.

THE western fourth of one-inch Sheet 109 (Achintoul), comprising parts of the deer forests of Ben Armine, Loch Choire, Borrobol and Badanloch, has been examined by Dr. H. H. Read. This area forms the eastward continuation of the Ben Klibreck district, in one-inch Sheet 108, described in last year's *Summary of Progress* (pp. 64-6). It was originally mapped mostly by the late Dr. C. B. Crampton in 1909-1913; a small area in Ben Armine forest was examined by Mr. M. Macgregor in 1911-1913, whilst in 1891-4 Dr. E. Greenly had surveyed the district east of Strath Naver. Its re-examination by Dr. Read was undertaken for three main reasons; the first, to extend eastwards the geological boundaries established in 1926 in Sheet 108, the second, to enquire into the significance of the "gneisses of Lewisian type" described chiefly by Dr. Crampton, and the third, to gather material for the Memoir on Sheets 108 and 109, now in preparation. Dr. Read gives the main conclusions resulting from his re-examination in the following report.

Moine Series and Granite Complex.—The range of the two Ben Armines, consisting of Creag a' Choire Ghlais and Creag Mhòr, affords on the east a series of magnificent crag-sections overlooking the peaty waste of Borrobol Forest. At the base of the crags is exposed a group of siliceous granulites and semipelitic schists with occasional lenses of hornblende-schist; threads and sheets of granite and pegmatitic material are not abundant at the lower levels but increase in size and number higher up. The group passes at a gentle angle beneath an intimate mixture of pelitic schists and granitic injections, in which the igneous component is dominant. At or about the junction of the pelitic country-rock above and the siliceous country-rock below, there occurs a persistent sheet, or group of sheets, of granite. This type of section continues from the Bealach na Muic at the south end of the Ben Armine range to Coire na Saidhe Duibhe at the north end, and can be followed from the latter locality north-westwards and then westwards into the Loch Coire hollow.

Topographically and geologically, Ben Armine is a repetition of Ben Klibreck. The lower siliceous zone of Ben Armine produces vertically-jointed precipitous crags like those formed by similar rocks at the Pap on Klibreck. Above this zone, at both Ben Armine

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and Ben Klibreck, appear jagged irregular crags of a complex of granitic material and pelitic schists. The geological sections of the two mountains are similar not only in the nature and the relations of the country-rocks, but in the character, amount and distribution of the injected igneous material. But the Ben Klibreck section faces west, the Ben Armine section east ; hence the conclusion that the pelitic schists of the Ben Armine, Loch Coire and Ben Klibreck area lie in some form of outlier or infold above the siliceous group seems a reasonable one. The margin of this outlier between Ben Armine and Ben Klibreck has been traced on the north side ; on the south side its course is more conjectural, being largely obscured by the high-level peat south of Loch Coire.

The siliceous rocks of the lower zone of Ben Armine and Loch Coire were styled " gneisses of Lewisian type " or even " Lewisian rocks " in the *Summaries of Progress* for the years 1910-1913. They were considered to be succeeded, possibly unconformably, by the upper pelitic zone which belonged to the Moine Series. The subject cannot be discussed adequately here, but there is no doubt that the siliceous and semipelitic rocks in question are typical siliceous granulites and semipelitic schists of the Moine Series and differ in no respects from undoubted Moine rocks occurring in the corresponding position on Ben Klibreck. With regard to the nature of the junction-plane between these " rocks of Lewisian type " and the overlying pelitic Moine schists, it may be stated that the detection of a plane of unconformity amid the igneous injections and complexes of the Ben Armine range is a problem of great difficulty. No such plane, however, is suspected at the corresponding position on Ben Klibreck.

Northwards from the localities just discussed, and eastwards towards Kinbrace, and the Griams, the rocks are complexes of siliceous, semipelitic and pelitic members of the Moine Series with varying amounts of granitic material. Here again, " rocks of Lewisian type " or of " Lewisian age " were considered to occur by Dr. Crampton (*Summary of Progress* for 1909, p. 39). In Dr. Read's opinion, however, all the country-rocks of these districts belong to types well-known in the Moine Series.

J. E. RICHEY.

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5. ORKNEY ISLANDS

J. E. RICHEY, M.C., B.A., District Geologist.
J. KNOX, B.Sc.
J. V. STEPHENS, B.Sc., B.ENG.
WILFRID EDWARDS, M.A.
R. C. B. JONES, M.C., M.Sc.
} Geologists.

THE survey of Orkney was begun during the past summer by Mr. Knox from the Scottish Staff together with Messrs. Stephens, Edwards and Jones from the Yorkshire and Lancashire units. On the Orkney mainland Mr. Knox and Mr. Stephens have surveyed areas in the vicinity of Kirkwall and Stromness respectively. Mr. Edwards has mapped South Ronaldshay, Burray and the smaller islands between South Ronaldshay and Caithness. Mr. Jones has completed certain of the northern islands including Sanday, Eday, and North Ronaldshay.

Granitic Complex of Stromness.—These rocks have long been known to underlie the Stromness Beds, the lowest subdivision of the Orcadian Middle Old Red Sandstone. Mr. Stephens' detailed mapping shows that the granite outcrop extending north-north-west through Stromness is not continuous, but consists of a number of small outcrops separated from one another by the overlying Stromness flagstones.[1] The old rocks are composed of a complex of granite and sedimentary schists, the latter being mainly similar to the Moine Schists of the North Highlands. The schists form outcrops of some extent which are fairly free from granite intrusions, and also occur in patchy fashion enclosed in or copiously injected by the granite. The complex exactly resembles in the field the extensive granite and Moine Schist complex of Sutherlandshire.[2]

Middle Old Red Sandstone.—The sequence and classification of these strata as described by Drs. Peach and Horne [3] and by Sir John Flett [4] form the basis of the work of the present survey. Additional information has so far been collected more especially with regard to the Eday or John o' Groats sandstones, which form

[1] *Cf.* A. G. Steavenson, 'Some Geological Notes on Three Districts of Northern Scotland, *Trans. Geol. Soc. Glasg.*, vol, xviii, pt. i, 1928, p. 216.

[2] Horne, J., and E. Greenly, 'On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherlandshire,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, pp. 633–648; H. H. Read *in* 'The Geology of the Country around Golspie,' Explanation of Sheet 103 (*Mem. Geol. Surv.*), 1925, pp. 21–40; *and in* 'The Geology of Strath Oykell and Lower Loch Shin,' Explanation of Sheet 102 (*Mem. Geol. Surv.*), 1926, pp. 148–152.

[3] Peach, B. N., and J. Horne, 'The Old Red Sandstone of Orkney,' *Proc. Roy. Phys. Soc. Edin.*, vol. v, 1880, pp. 329-342.

[4] Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edin.*, vol. xxxix, pt. ii, 1898, pp. 383-424.

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the upper portion of the Middle Old Red Sandstone of Orkney and Caithness. These beds have been examined chiefly in Eday and Sanday and in South Ronaldshay and Burray. In both of these areas a transition group between the underlying Rousay flags and the Eday sandstones has been mapped by Messrs. Jones and Edwards. This group consists of thin, siliceous sandstones interbedded with the Rousay flags for a short distance below the first thick sandstone met with. The base of the latter is taken as the base of the Eday Beds proper. Some 300-600 ft. above this base in Sanday and Eday a group of flags is interbedded in the sandstones from which, north of Strang Quay in Sanday, *Tristichopterus alatus* has been collected. In South Ronaldshay, flags corresponding closely in stratigraphical position to the above-mentioned group have also yielded *Tristichopterus alatus* together with *Pentlandia* (*Dipterus*) *macropterus* (p.75). These records of *T. alatus* supplement Sir John Flett's [1] original discoveries of this species in Orkney from flags interbedded with the Eday sandstones of Shapinshay and the eastern Mainland.

The thicknesses of the Eday Beds in Eday have been estimated by Mr. Jones. He finds that the Lower Eday Beds (excluding the transition group), which consist mainly of pebbly yellow and red sandstone, are 1,700-2,000 ft. thick, while of the Upper Eday Beds, composed of red marls and fine-grained sandstones usually red, 2,800 ft. are seen. In South Ronaldshay the sequence is repeatedly interrupted by faults, and estimates of thickness made by Mr. Edwards are consequently only approximate. In the area including the northern half of this island and Burray the Lower Eday Beds are about 1,400-2,000 ft. thick, and the Upper Eday Beds (top not seen) about 1,600 ft.

Faults.—While there is no doubt that the majority of the faults traversing the Orkney Old Red Sandstone are normal, a good example of a reversed fault is noteworthy. This fracture extends N.-S. adjacent to the eastern shore of Scapa Bay, where it has been mapped by Mr. Knox. It is admirably displayed in a cliff opposite Gaitnip, heading to the east at 55°, and bringing up the Rousay flags to the east against the Eday Beds to the west.

Pleistocene.—Striae and foreign boulders in the boulder-clay have been noted which confirm Drs. Peach and Hornes' [2] well-established conclusion regarding the passage of an ice-sheet northwestwards over the Orkneys bearing Scottish mainland boulders.

J. E. RICHEY.

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[1] Flett, Sir. J. S., *op.cit.*, pp. 385 and 412-414.

[2] Peach, B. N., and J. Horne, 'The Glaciation of the Orkney Islands,' *Quart. Journ. Geol. Soc.*, vol. xxxvi, 1880, pp. 648-663; 'On the Occurrence of Shelly Boulder Clay in North Ronaldshay, Orkney,' *Trans. Edin. Geol. Soc.*, vol. vi, 1893, pp. 309-313.

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III. SECTIONAL REPORTS

1.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, SC.D., PH.D., Palaeontologist (District Geologist).
J. PRINGLE, Assistant-Palaeontologist
C. P. CHATWIN, M.SC., Assistant-Palaeontologist } (Senior Geologists).

In Edinburgh

G. W. LEE, D.SC., Senior Geologist.

1. ENGLAND AND WALES

A CROWDED programme of work, chiefly connected with the preparation of memoirs, has been carried out in the department, and the results will eventually appear in these publications. In the course of this work there has emerged little of outstanding interest to which attention should here be drawn.

Practically no palaeontological work has been done in the Coalbrookdale coalfield since the publication of Prestwich's memoir in 1845. For the purpose of the forthcoming memoir on the Wolverhampton sheet Mr. Pringle revised the fossils in the Museum from the Coal Measures of that district, particularly those from the well known marine horizon, the Pennystone Ironstone. Species of *Spirifer* from this horizon, recognized by Mr. Pringle as undescribed forms, have been investigated by Mr. T. N. George, whose account of them is now awaiting publication. Mr. Pringle and Dr. R. Crookall visited sections in Coalbrookdale and contributed a joint account of the palaeontology of the Coal Measures, which will appear in the memoir.

Mr. Pringle has paid a further visit to the locality near Gilsland (North Cumberland) which yielded the new brachiopods mentioned in the previous year's *Summary of Progress* (p. 68). He secured an exceptionally fine example of *Crossochorda tuberculata* Williamson from the same beds (S_2) in the Limestone Series. This has now been placed in the Museum collection.

During his field-work in connexion with the revision of the Merthyr Tydfil sheet, Mr. Pringle examined fossils from the Brass Vein, and in the material studied he recognized a new species of *Belinurus*. He hopes to obtain more material and to publish a description of this form. During an unofficial visit to the sand-pits at Billington Crossing, Leighton Buzzard, he secured an example of a new species of *Cleoniceras* from the *regularis* subzone of the Albian. This specimen has been presented to the Museum and has been figured by Dr. Spath as *Cleoniceras morgani*, in his monograph on the 'Ammonoidea of the Gault.' This makes an interesting addition to the known species of the *regularis* subzone, which has so little representation in this country.

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Further material has been obtained from the ironsands yielding late Pliocene fossils on Netley Heath. From the abraded condition of 45 lumps of fossiliferous ironsand obtained by Mr. F. H. Edmunds, it seems evident that these occur as boulders in a gravel. In last year's *Summary of Progress* Mr. Chatwin commented on the frequent occurrence in the ironsand of *Corbulomya complanata* Auctorum. This is confirmed by the finding of 8 examples of this shell in two lumps of ironstone presented during the year by Mr. W. Wright.

Mr. Chatwin has revised a number of cases of Chalk fossils in the Museum and has arranged a new exhibit showing the chief faunal characters of the successive zones of the Chalk. The plan adopted will meet the demand for a narrower subdivision of the strata under each formation in the exhibited collection ; and it is hoped to extend this method of treatment to other parts of the stratigraphical series of fossils shown in the Museum.

The following specimens in the Museum have been figured, described or mentioned in publications :—

IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1925 (Published 1927).

A Monograph of the British Palaeozoic Asterozoa. (Part vii). By DR. W. K. SPENCER, M.A., F.G.S.

Stenaster obtusus (*Forbes*), pl. xxiii, figs. 8, 9, p. 356.
Onychaster barrisi (*Hall*), pl. xxi, fig. 13 ; text-figs. 219, 220, p. 340.

A Monograph of the Ammonoidea of the Gault. (Part v). By DR. L. F. SPATH, F.G.S.

Callihoplites *aff.* auritus (*J. Sowerby*), pl. xvii, fig. 1 ; text-fig. 61, p. 197 (4 specimens).
,, variabilis *Spath*, pl. xviii, fig. 2, p. 202 (2 specimens).
,, horridus *Spath*, pl. xviii, fig. 9 ; text-figs. 62a, b, p. 200 (2 specimens).
,, formosus *Spath*, pl. xix, figs. 5a, b, p. 196.
,, patella *Spath*, pl. xx, fig. 5, p. 192.
,, strigosus *Spath*, *var.* cristatus *Spath*, text-fig. 59, p. 195.
,, tetragonoides *Spath*, p. 204.
Cleoniceras morgani *Spath*, pl. xvii, fig. 7 ; pl. xviii, fig. 5.

A Monograph of the Fossil Macrurous Crustacea of England. (Part iv). By MR. H. WOODS, M.A., F.R.S.

Glyphea *cf.* tomesi *H. Woodward*, pl. xiii, figs. 3a, b, p. 49 (2 specimens).
,, cretacea *McCoy*, p. 62.

A Monograph of British Dendroid Graptolites. (Part i). By DR. O. M. B. BULMAN, D.I.C., A.R.C.S., F.G.S.

Dictyonema flabelliforme (*Eichwald*), *var.* sociale (*Salter*), pl. ii, fig. 1 ; text-fig. 15, p. 26 (2 specimens).

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IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, VOLUME CCXVI.

II. *The Corallian Rocks of Oxford, Berks and North Wilts.*
By MR. W. J. ARKELL, B.A., B.Sc., F.G.S.

Cyprina corallina *d'Orbigny*, pl. i, fig. 5.
Terebratula kingsdownensis *Arkell*, p. 175 (8 specimens).

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXIII.

A Revision of the Non-Marine Lamellibranchs of the Coal Measures and a discussion of their Zonal Sequence.
By MR. J. H. DAVIES, F.G.S., AND DR. A. E. TRUEMAN, F.G.S.

Carbonicola sp., pl. xvi, figs. 5a, b, (2 views), p. 245.
Anthracomya (?) sp. nov., pl. xvii, figs. 8a, b, (2 views), p. 245.

A Critical Revision of the Rugosa Corals described by W. Lonsdale in Murchison's 'Silurian System.'
By DR. W. D. LANG, M.A., F.G.S., AND DR. STANLEY SMITH, M.A., F.G.S.

Tryplasma flexuosum (*Linnaeus*), pl. xxxiv, figs. 1a—c, p. 464; text-figs. 11, 12, p. 461.
Arachnophyllum murchisoni (*Edwards and Haime*), pl. xxxiv, figs. 2, 3, p. 467.
,, diffluens (*Edwards and Haime*), pl. xxxiv, fig. 4, p. 468.
Patrophontes truncatus (*Linnaeus*), pl. xxxv, fig. 4, p. 474.
Acervularia ananas (*Linnaeus*), *var.* truncata (*Wahlenberg*), pl. xxxv, figs. 6—8, p. 474.
Xylodes pseudodianthus (*Weissermel*), pl. xxxv, fig. 9, p. 475.
Cystiphyllum cylindricum *Lonsdale*, pl. xxxvi, figs. 1—3, p. 477.
,, siluriense *Lonsdale*, p. 476.
Acanthocyclus binus (*Lonsdale*), pl. xxxvii, fig. 5, p. 483.
'Turbinolopsis' elongata *Phillips*, pl. xxxvii, figs. 6, 7, p. 484.
Phaulactis angusta (*Lonsdale*), p. 469 (2 specimens).
Chonophyllum (?) patellatum (*Schlotheim*), p. 482 (3 specimens).
Palaeocyclus porpita (*Linnaeus*), text-fig. 17, p. 486 (3 specimens).

The Occurrence, Structure, and Affinities of Echinocystis and Palaeodiscus.
By PROF. H. L. HAWKINS, D.Sc., F.G.S., AND MISS S. M. HAMPTON, B.Sc.

Echinocystis pomum *Wyville Thomson*, pl. xliv, fig. 1, p. 581 (2 specimens).
Palaeodiscus ferox *Salter*, pl. xliv, fig. 2, p. 588; text-fig. 5, p. 590.

IN THE ANNALS AND MAGAZINE OF NATURAL HISTORY, VOLUME XIX, NINTH SERIES.

Two new Species of Lower Carboniferous Brachiopoda from Northumberland.
By MISS H. M. MUIR-WOOD, M.Sc., F.G.S.

Pustula thomasi *Muir-Wood*, text-figs. 1, 2, p. 288.
Punctospirifer northi *Muir-Wood*, text-figs. 3—6, p. 290.

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In the Geological Magazine, Volume LXIV.

Bernicia praecursor *gen. & sp. nov., a Lower Carboniferous Fresh-water Gasteropod.*

By Mr. L. R. Cox, M.A., F.G.S.

Bernicia praecursor *Cox*, text-fig. 1, (3 views), p. 327.

In the Memoirs and Proceedings of the Manchester Literary and Philosophical Society, Volume LXXI.

X.—*New Carboniferous Lamellibranchs and Notes on other Forms.*

By Mr. J. Wilfrid Jackson, M.Sc., F.G.S.

Pterinopecten papyraceus (*J. Sowerby*), pl. i, fig. 1 ; pl. ii, fig. 5, p. 96.
,, elegans *J. W. Jackson*, pl. i, fig. 2 ; pl. ii, fig. 4, p. 103.
,, speciosum *J. W. Jackson*, pl. i, figs. 3, 4 ; pl. ii, fig. 3, p. 105.
,, rhythmicus *J. W. Jackson*, pl. ii, fig. 2, p. 107.
Posidonomya insignis *J. W. Jackson*, pl. iii, fig. 3, p. 114 (5 specimens).
,, minor (*Brown*), pl. iii, fig. 7, p. 116.
,, rugata *J. W. Jackson*, pl. iii, figs. 8, 9, p. 117 (3 specimens).
,, multirugata *J. W. Jackson*, pl. iii, figs. 10—12, p. 118 (7 specimens).

In Type Ammonites, Volume VI.

By Mr. S. S. Buckman, F.G.S.

Vermidactylites vermis (*Simpson*), pl. lxviiiA, figs. 1, 2.
Lunuloceras lonsdalii (*Pratt*), pl. diiA.
Xeinodactylites helianthoides (*Yokoyama*), pl. dcxcix, figs. 1—3.
Dactylioceras annulatum (*J. Sowerby*), pl. dcc, p. 43.
Prionodoceras truculentum *S. Buckman*, pl. dcciv, figs. 1, 1a, 2.
Simplidactylites simplicicosta *S. Buckman*, p. 43 (2 specimens).
Parvidactylites parvus *S. Buckman*, p. 43.

In Type Ammonites, Volume VII.

By Mr. S. S. Buckman, F.G.S.

Pseudocadoceras ? laminatum *S. Buckman*, pl. dccxxvii.
,, ? concinnum *S. Buckman*, pl. dccxxxv.
Nodicoeloceras crassoides (*Simpson*), pl. lxxxixA, figs. 1, 2.
,, acanthus (*d' Orbigny*), pl. dccxxixA ; pl. dccxxixB.
Allovirgatites distans (*Neaverson*), pl. dcxxxviiic ; pl. dcxxxviiiD.
Crassicoeloceras pingue *S. Buckman*, pl. dccxxviii, figs. 1, 2.
Lobodactylites lobatum *S. Buckman*, pl. dccxxx, figs. 1, 2.
Orthodactylites nitis *S. Buckman*, pl. dccxxxviii, figs. 1, 2.
Harpoceratoides strangwaysi (*J. Sowerby*), pl. dccxxxix, figs. 1, 2.
Glyptarpites glyptus *S. Buckman*, pl. dccxl, figs. 1—3, p. 9.
Tardarpoceras tardum *S. Buckman*, pl. dccxli, figs. 1—3, p. 9.
Harpoceras concinnum *S. Buckman*, pl. dccxlii, figs. 1, 2.

In Memoirs of the Geological Survey, England.

The Geology of the Rossendale Anticline.

Chapter IX.—*Palaeontology.*

By Mr. W. B. Wright, M.I.M.E., F.G.S.

Reticuloceras reticulatum, *early mut.* γ, *mut. nov.*, pl. vi, figs. 1, 2, 6, p. vii (3 specimens).
Gastrioceras lineatum *Wright*, pl. vi, figs. 3, 4, 8, p. vii (3 specimens).
Gastrioceras ? sigma *Wright*, pl. vi, figs. 5, 7, p. vii (2 specimens).

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2. Scotland

Dr. Lee reports that as most of the Carboniferous materials were obtained from the cores of borings, large suites of well preserved fossils were not available for detailed study. In spite of this limitation, a point of both faunistic and stratigraphical interest has been brought to light, which may prove of use in determining positions within the Millstone Grit of Stirlingshire and Clackmannanshire.

Two borings put down some miles south-west of the Forth, and one south of Dollar, north-east of the Forth, have revealed the presence of a marine band characterized by *Productus carbonarius* de Koninck, *P. cora* d'Orbigny [Tschernyschew] (not of British authors), and a new species of *Productus* with extremely fine striation. That this marine horizon persists over a fairly wide area is shown by the fact that the same forms, among others, were found in a natural section (Rough Cleuch burn) three miles south-east of Dollar. This horizon is considerably higher up in the Millstone Grit sequence than that at the base of the formation from which the late Dr. Wheelton Hind described a lamellibranch-fauna of North American Upper Carboniferous facies.

The Survey is indebted to Mr. Wallace Thorneycroft, of the Plean and Lochgelly Collieries, for drawing attention to another point of considerable stratigraphical value. He sent for examination a suite of fossils obtained from the roof of the 'Coal Stink' of the Mary Pit, Lochgelly, Fife, which proved to be purely marine, with certain elements in common with the marine fauna of the roof of the 'Smithy Coal' of Bo'ness, in Linlithgowshire.

Numerous fossil fishes were obtained from the Old Red Sandstone by the members of the Orkneys unit during the summer of 1927, and the following notes concerning them are supplied by Prof. D. M. S. Watson, F.R.S., who has examined the collection:—

'The materials collected from the Stromness Beds at various localities in the parishes of Stromness and Sandwick give a nearly complete representation of the well known fauna, which occurs in this area and also at Achanarras, Caithness, and in the Moray Firth nodule localities.

'The commonest fish are those which I have referred to "*Osteolepis macrolepidota*," using this specific name in the sense of Traquair and Smith Woodward. It is perfectly clear that even amongst the present specimens two or three species are included under this head; none of these is identical with the form which is abundant at Tynet Burn, Banffshire, nor are any certainly the same as the Gamrie fish. The differences are only recognisable in well preserved specimens which show the structure of the head. I hope to bring together a series of these fish from all the localities in which they occur, and then distribute them amongst a number of species.

'Little of the material from the parish of Kirkwall is specifically determinable and, so far as collecting has been carried out, no

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recognisable specimens of the fish characteristic of the horizon of Thurso have been found to be present.

'There are, however, two specimens of interest from the Rousay Beds of the parish of Kirkwall: No. T.4413g, the fronto-ethmoidal shield of a large Osteolepid, is certainly undescribed and of unusual structure. No. T.4436g, from 420 yards E. 8° N. of Inganess Farm, 1½ miles S.E. of Kirkwall, is part of the skeleton of a large Coccosteian. It differs from *C. decipiens* most markedly by the absence of a spine at the posterior end of the dorso-median plate, and in many details of proportion of all the bones. It is certainly specifically new and may have to be referred to a new genus.

'The Natural History Museum contains a single specimen of the same form, which came from Dr. R. H. Traquair's collection and bears the name "Newark" scratched on the back. I have reasons for believing that this is the specimen determined by Traquair as *C. decipiens*, which is said by Flett [1] to have been found by Mr. M. Spence in the Eday sandstones of Newark Bay, Deerness. It is an interesting fact that this form, although now known from two localities, has not yet been found in association with *Tristichopterus*: it is possible that it is restricted to a definite horizon. In any case, it is very desirable that further collecting should be carried out at the localities at which it has been found.

'The collections from S. Ronaldshay are interesting. From the Rousay flags of a quarry near Helliar there is a badly preserved bone which is apparently a posterior ventro-lateral of an Antiarchan, differing from any which I know; but perhaps the *Asterolepis* found immediately below the Eday sandstones in several localities, including N. of Sandside, Deerness.

'The Rousay flags of Bloie Geo, Hoxa Head, have yielded a fragment apparently of *Osteolepis microlepidota*, not previously recognised from Orkney.

'A flagstone band in the yellow sandstones (Lower Eday Beds) of the Steis, Harrabrough Head, has yielded a number of good specimens of *Tristichopterus alatus* Eg. and *Pentlandia* (*Dipterus*) *macropterus* (Traq.), but no remains of *Microbrachius*. These are typical of the John o' Groats Beds, the equivalent of the Eday Beds, as pointed out by Flett.[2]

'*Tristichopterus alatus* Eg. is again represented by a fish from a loose block on the beach north of Strang Quay, Sanday.

'From 150 yards west of Dogs Geo, Muckle Skerry, Pentland Skerries, there are three specimens of *Coccosteus decipiens*, showing that the horizon is below the Eday Beds.'

F. L. KITCHIN.

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[1] Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edinb.*, vol. xxxix, part ii, 1898, pp. 386, 387.

[2] *Op.cit.*, p. 420.

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2.—PALAEOBOTANICAL WORK

With the assistance of Mr. S. W. Morgan of the Palaeontological Department, work has been continued on the catalogue of specimens in the Kidston Collection of fossil plants, and this is now complete and ready for the press. Specimens which have been figured, described, or specially mentioned have been indicated in the catalogue in the form of footnotes. The collection comprises over 7,000 specimens, of which 840 have been figured, and these include 167 type specimens. All available information with regard to the fossils has been given. The collection has already been made considerable use of by palaeobotanists.

My services have been required in the field on several occasions this year. Mr. J. Pringle and I have visited two coalfields and our joint work on the Coalbrookdale area is embodied in the Wolverhampton Memoir now in the press. In South Wales we visited the Merthyr district, at present undergoing revision, and collected a large and representative suite of fossil plants and animals from the Coal Measures and Millstone Grit. The results of this work will duly appear in the second edition of the Merthyr Memoir. During the course of the work in South Wales a number of fragments of fossil wood were obtained from the Ganister Quarry, half a mile W.S.W. of Pant Station, near Dowlais. These are of special interest in view of the specimen of petrified wood previously collected by Mr. Pringle from the ' Penlan Quartzite ' and identified by Mr. J. Walton as *Dadoxylon* cf. *materiarum* Dawson.[1] This was a fairly large block in an exceptionally good state of preservation, but the pieces now found are small and badly preserved. It was not possible to obtain more than one section from each specimen. The fossils can be identified, however, as *Dadoxylon sp.*, and this constitutes the second record of the genus from the basal quartzite of the Millstone Grit.

I have collected a number of fossil plants from the exceedingly barren horizon of the Pennant Rock (Staffordian Series) of the Somerset and Bristol Coalfield, and these will be described at a later date.

Amongst the specimens examined during the year was a piece of gymnospermous wood collected by Mr. J. W. Tutcher, M.Sc., from the upper part of the Bucklandi Zone of the Lias at Rockhill, near Radstock. The wood was badly preserved, but the pitting on the radial walls appears to be multiseriate, and some of the tracheids are resiniferous. The xylem-rays are comparatively few and range from 2 to 5 cells in height. No pits are observable on their radial walls, and resin canals and xylem-parenchyma are absent. The specimen is referred to *Dadoxylon sp.* Other pieces of fossil wood from the Lias at Keynsham, near Bristol, were sent in by Mr. A. W. Coysh. They had the appearance of jet, but, on being sectioned, showed no structure. R. CROOKALL.

[1] ' Summary of Progress ' for 1926, Appendix V, p. 126, pl. 1.

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3.—PETROGRAPHICAL WORK

The work of the Petrographical Department has been connected mainly with the areas recently surveyed or in progress of surveying.

The re-survey of the Cheviot region by Messrs. Anderson and Burnett has largely substantiated the work of Kynaston and other observers who had paid special attention to the rocks of this district.

The great mass of lavas of Old Red Sandstone age are remarkable for their consistency. They are mainly augite and pyroxene andesites occasionally showing a distinct leaning towards an albitic or dacitic facies.

The granite has been found to be somewhat variable both in texture and composition, but generally rich in albitic and perthitic felspars. Recent work has demonstrated that it becomes at its margin a fine textured granophyre that has tongued and veined the rocks into which it has been intruded. This marginal portion shows local contamination by the partial or complete absorption of xenolithic material derived mainly from the andesitic lavas. Further, it has produced an intense metamorphism of the older rocks with which it comes in contact. The lavas for some hundred yards from the main contact show more or less complete recrystallization, especially in the ground-mass, into fine textured pyroxene-granulites. The extreme metamorphic effects of the granite are very well displayed in the highly-veined cappings of lava which rest upon the granite, well within its peripheral limits. These cappings are of particular interest for they aid considerably any deliberations as to the mode and form of the main intrusion, as well as furnish us with the best examples of contact-phenomena.

The re-survey has shown that the dykes which include porphyrites, quartz-porphyries and felsites cannot be separated as regards age from each other, and in no case has the granite margin been observed to truncate any of them. All types alike appear to cut the granite and to be a later phase of intrusion. The radial distribution of the dykes with regard to the granite has been endorsed, but their number has been found to be much greater than was previously supposed.

The granite itself, as is well known, differs from most other British granites in containing both augite and rhombic pyroxene. The occurrence of these ferromagnesian minerals, which are absent from the marginal portion of the mass except where provedly xenolithic, appears to be sporadic, and their existence as normal constituents of the granite is open to question.

The variability of the granite and the presence of unusual ferromagnesian constituents are features that will be made a matter of special concern, and on which a considered opinion as to their significance will be given at a later date.

Tourmaline has been described as a local constituent of the

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granite, but until the re-survey it was not realized that this mineral had a wide distribution. On the north side of the granite-mass the granophyric marginal variety has been subjected to more or less intense pneumatolytic action with the destruction of felspar, the development of pneumatolytic micas, and the widespread crystallization of tourmaline. In some cases the resulting rocks compare quite closely with the luxullianite and other tourmaline-bearing rocks of Cornwall and Devon.

The pneumatolytic effects are not confined to the granite alone, but have occasionally spread well into the metamorphic zone of the granite, where the Lower Palaeozoic sediments have been highly tourmalinized.

That this pneumatolytic phase represents a late stage in the intrusive history of the Cheviot rocks is clearly demonstrated by the fact that tourmalinization has in certain cases spread to the porphyritic dykes that cut the granite and which are the latest expression of the intrusion of the granite magma. Further, there has been mineralization with attendant tourmalinization of certain north-and-south crush-lines that traverse the granite and which must have been formed well after its consolidation.

H. H. THOMAS.

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4.—CHEMICAL WORK

The quantitative determinations completed in 1927 were mainly for the Scottish Memoirs, though some interesting specimens from Cornwall have also been analysed.

841. *Albite-diabase.* Intrusion. South side of Newlyn Pier, Land's End. 6-in. map, Cornwall, 74. S.W. Slice No. E13479.

842. *Diabase-hornfels.* Carn Kenidjack, N.W. of St. Just. 6-in. map, Cornwall, 67 S.W. Slice No. E13481.

862. Mineral, probably *Cummingtonite.* Contact-altered Greenstone. Kenidjack, near St. Just. 6-in. map, Cornwall, 67 S.W.

849. *Granite.* At edge of Bodmin Moor Mass. De Lank Quarry. St. Breward, near St. Tudy. 6-in. map, Cornwall, 20 S.E. Slice No. E13907.

843. *Porphyry.* Inclusion in granite. From new shaft of Botallack Mine, W.N.W. of St Just 6-in. map, Cornwall, 67 S.W. Slice No. E13480.

Lab. Nos.	841	842	862	849	843
SiO_2	61.59	47.07	53.12	71.86	68.89
Al_2O_3	17.85	20.20	2.78	14.63	15.11
Fe_2O_3	2.19	0.00	0.25	0.15	0.37
FeO	4.30	12.73	22.46	1.26	3.14
MgO	1.02	10.09	15.46	0.66	0.70
CaO	0.53	2.14	2.26	0.87	1.21
Na_2O	7.36	1.48	—	2.92	2.35
K_2O	1.95	1.97	—	5.32	5.66
$H_2O \geq 105°C$ ...	1.71	1.50	3.33	0.84	1.05
$H_2O < 105°C$ ...	0.55	0.16	—	0.15	0.25
TiO_2	0.71	2.12	0.21	0.50	0.74
P_2O_5	0.12	0.12	—	0.42	0.38
MnO	0.11	0.11	0.27	0.06	0.02
ZrO_2	—	—	—	0.02	0.01
F	0.00?	—	—	0.03	0.04
FeS_2	0.11	0.47	—	0.31	0.12
Cr_2O_3	—	0.02	—	—	—
BaO	—	—	—	0.03	0.03
Li_2O	—	0.03	—	0.00	0.02
Less O for F ...	—	—	—	0.01	0.02
Totals ...	100.10	100.21	100.14	100.02	100.07
Analysed by ...	B. E. Dixon.		R. Sutcliffe.		B. E. Dixon.

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837. *Nepheline-basalt*, with nepheline partly fresh and olivine decomposed. Lava of New Red Sandstone (? Permian) age. Quarry, 450 yds. E. 5° N. of Grassmilees, ¾ m. S.E. of Mauchline. 6-in. map, Ayrshire, 29 S.W. Slice No. S25241.

838. *Olivine-basalt*, with olivine fresh and doubtful pseudomorphs after Nepheline. Lava of New Red Sandstone (? Permian) age. E. end of railway cutting, Tarbolton Station. 6-in. map, Ayrshire, 28 S.W. Slice No. S25246.

839. *Alkaline Olivine-dolerite* or *Olivine-basalt*, of Kylite suite, with fresh porphyritic olivine and augite, and with nepheline mostly decomposed. Sill of New Red Sandstone (? Permian) age, intruded into Millstone Grit. Quarry, Craigs of Kyle, 1¼ m. W.N.W. of Rankinston Station. 6-in. map, Ayrshire, 40 N.W. Slice No. S25252.

840. *Hypersthene-andesite*, with fresh felspars, including small labradorite phenocrysts, and also partially fresh hypersthene. Lava of Lower Old Red Sandstone age. Near shore, 540 yds. N.W. by W. of Dunure Station. 6-in. map, Ayrshire, 38 N.E. Slice No. S25255.

864. *Hornblende-trachyandesite*. Lava flow. Right bank of Cleuchearn Burn, 250 yds. 10° E. of S. of E. corner of Cleuchearn Lodge, East Kilbride. 6-in. map, Lanarkshire, 22 N.E. Slice No. S25755.

865. *Pyroxene-trachyte* or *Trachyandesite*. Lava flow. 115 yds. N.N.W. of summit of Drumreevough, Avondale. 6-in. map, Lanarkshire, 22 S.E. Slice No. S25756.

Lab. Nos.	837	838	839	840	864	865
SiO_2	39.35	45.62	45.70	58.88	54.66	59.57
Al_2O_3	11.60	14.18	12.32	15.86	15.90	16.12
Fe_2O_3	9.31	2.95	0.99	2.49	3.06	3.44
FeO	4.76	8.40	9.64	3.46	4.11	3.11
MgO	10.58	9.69	12.45	4.40	2.91	1.46
CaO	10.55	9.25	10.12	5.75	3.91	2.65
Na_2O	3.06	3.61	2.74	2.70	4.66	6.03
K_2O	0.86	1.48	1.64	2.02	3.81	4.34
$H_2O >$ 105°C ...	3.76	2.29	2.12	0.65	2.13	1.08
$H_2O <$ 105°C ...	1.44	0.27	0.16	1.74	1.83	0.63
TiO_2	3.38	1.61	1.50	1.17	1.48	0.77
P_2O_5	0.82	0.47	0.33	0.22	0.43	0.21
MnO	0.79	0.32	0.29	0.52	1.14	0.78
CO_2	0.19	0.05	0.07	0.09	0.24	0.12
Cl	0.05	0.03	0.01	0.00?	—	—
FeS_2	0.03	0.00	0.00	0.00	—	—
NiO, CoO	0.03	0.03	0.02	0.03	0.00	0.00
BaO	0.01	0.02	0.03	0.04	0.12	0.13
Li_2O	0.00?	0.00	0.00?	0.00?	0.00?	0.00?
Less O for Cl ...	0.01	0.01	—	—	—	—
Totals ...	100.56	100.26	100.13	100.02	100.39	100.44
Analysed by ...	E. G. Radley.					

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854. *Staurolite-garnet-mica-schist.* Belt in Moine Series. ⅛ m. S.E. of Cairn on Cnoc an Daimh Beag, 1⅛ m. E. of Loch Meadie. 6-in. map, Sutherland, 43 S.W. Slice No. S25686.

856. *Modified Pelitic Schist* within Granite Complex (early stage). Part of Moine Series and Granite Complex. 2¼ m. S.E. by S. of Klibreck Farm. 6-in. map, Sutherland, 54 S.W. Slice No. S25688.

855. *Modified Pelitic Schist* within Granite Complex (middle stage). Part of Moine Series and Granite Complex. 2⅜ m. S.E. by S. of Klibreck Farm. 6-in. map, Sutherland, 54 S.W. Slice No. S25687.

857. *Modified Pelitic Schist* within Granite Complex (advanced stage). Part of Moine Series and Granite Complex. 2⅛ m. of S.E. of Klibreck Steading. 6-in. map, Sutherland, 54 S.W. Slice No. S25689.

Lab. Nos.	854	856	855	857
SiO_2	63.98	61.11	62.28	59.25
Al_2O_3	17.68	18.33	17.69	18.48
Fe_2O_3	2.23	1.14	1.09	1.24
FeO	4.76	5.47	5.25	6.78
MgO	3.18	1.75	1.67	2.30
CaO	1.05	1.66	2.29	2.51
Na_2O	1.10	2.64	3.25	3.78
K_2O	4.16	4.41	3.60	3.64
$H_2O >$ 105°C ...	1.18	1.51	1.43	0.72
$H_2O <$ 105°C ...	0.10	0.13	0.13	0.12
TiO_2	0.85	1.15	1.08	1.18
P_2O_5	0.08	0.08	0.08	0.08
MnO	0.05	0.11	0.07	0.08
CO_2	—	0.00?	—	—
F	—	0.00?	0.00?	—
FeS_2	0.00?	0.22	0.04	0.00?
Fe_7S_8	—	0.12	—	0.00?
Cr_2O_3	0.01	0.02	0.02	0.00?
BaO	0.00?	0.06	0.00	0.05
Li_2O	0.00?	0.00?	0.00?	0.00?
Totals ...	100.41	99.91	99.97	100.21
Analysed by ...	B. E. Dixon.			

850. *Pitchstone* (Corriegills Type). 20 ft. sill in New Red Sandstone. Lower pitchstone scarp above path near South Corriegills, ¼ m. E.S.E. of Dun Dubh (the more northerly of two sills midway between Dun Dubh and Dun Fioun), Arran. 6-in. map, Bute (Arran), 250 N.W. Slice No. S25614.

851. *Olivine-bearing Pitchstone* (Glen Shurig Type). Dyke in Old Red Sandstone. Farm road, 65 yds. from String Road, at B.M. 244.8, Glen Shurig, ½ m. S.W. of Brodick Church, Arran. 6-in. map, Bute (Arran), 244 S.E. Slice No. S25615.

852. *Pitchstone* (Tormore Type). Composite dyke (Judd's No. 2 Dyke —*vide* Q.J.G.S., vol. xlix, 1893, p. 555). Tormore shore, S. of Machrie Bay, Arran. 6-in map, Bute (Arran), 248 S.E. Slice No. S25621.

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853. *Tholeiite* (cf. Brunton type) associated with pitchstone. Basic member of pitchstone tholeiite composite dyke (Judd's No. 2 Composite Dyke). Tormore Shore, S. of Machrie Bay, Arran. 6-in. map, Bute (Arran), 248 S.E. Slice No. S25622.

Lab. Nos.	850	851	852	853
SiO_2	73.20	72.33	71.51	54.52
Al_2O_3	10.75	10.45	10.55	14.53
Fe_2O_3	0.95	1.00	0.79	2.21
FeO	1.02	2.14	2.22	6.06
MgO	0.15	0.11	0.52	5.61
CaO	0.76	1.44	1.52	8.08
Na_2O	3.78	4.09	4.12	3.66
K_2O	4.20	3.49	3.48	1.14
$H_2O > 105°C$ ...	4.52	4.02	4.07	0.93
$H_2O < 105°C$ ...	0.18	0.16	0.19	1.95
TiO_2	0.16	0.30	0.33	0.87
P_2O_5	0.19	0.16	0.24	0.21
MnO	0.37	0.50	0.42	0.24
NiO, CoO	0.00	0.00	0.00	0.00
BaO	0.05	0.08	0.08	0.03
Li_2O	0.00	0.00?	0.00	0.00
Totals ...	100.28	100.27	100.04	100.04
Analysed by ...	E. G. Radley.			

R. Sutcliffe.

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I.—A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffordshire

By W. F. P. McLintock, D.Sc., and J. Phemister, M.A., B.Sc.

Plates I, II ; Text-figures 1 to 8.

In the *Summary of Progress* for 1926 an account was given of the use of the Eötvös Torsion Balance in the investigation of geological structure in south-west Persia and the results there described seemed sufficiently promising to warrant the Survey in employing the method in this country. Accordingly in the spring of this year an instrument was acquired from Messrs. L. Oertling, Ltd., of type similar to that described in their handbook[1] and fully discussed by Captain Shaw and Mr. Lancaster-Jones in a recent series of articles in the Mining Magazine[2]. A preliminary note on the first field test with this balance has already appeared[3], but in view of the increased interest now being taken in geophysical methods of investigation and the lack of published details of actual field work, the fuller account that follows may, it is hoped, be of service to those interested in gravitational surveys.

THE INSTRUMENT

The large-size Eötvös Torsion Balance as made by Messrs. Oertling is so constructed that it may be used both for photographic and visual observation. Prior to work in the field, a series of tests was carried out in the laboratory and it was found possible by both methods of observation to measure gradients accurately to 1E (= 1×10^{-9} c.g.s. units). Slabs and cylindrical cores of rock of definite dimensions and weights were placed at known distances from the balance and their gravitational effects measured. These when compared with the values obtained by calculation gave satisfactory agreement.

In the field, however, several disturbing factors prevent the balance from working so smoothly and accurately. These have been noted by previous workers and in the most modern type of instrument and protecting tent attempts have been made to eliminate the disturbances with, as far as our experience goes, only partial success.

Thus we found it impossible to get reliable readings during the day. Visual observation on several days showed that the beams were never actually at rest even when left for several hours in one azimuth, the progressive change over a period of four or five hours amounting in some cases to as much as 40 scale divisions. Shortly after sunset the balance settled down and gave good repeats in the various azimuths till sunrise when the disturbance was almost

[1] '*The Eötvös Torsion Balance*,' L. Oertling, Ltd., London.

[2] 'The Theory and Practical Employment of the Eötvös Torsion Balance,' *Mining Magazine*, vol. xxxvi, 1927, pp. 201-212, 274-282, 339-347 ; vol. xxxvii, pp. 14-22.

[3] 'A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffordshire,' *Mining Magazine*, vol. xxxvii, 1927, pp. 362-365.

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immediately manifested and readings ceased to be satisfactory.

Photographic recording was also found to be uncertain. By this method the readings are taken automatically each hour successively in the various azimuths on a photographic plate, the process being controlled by clockwork attached to the balance and its protecting tent. In the laboratory this method works satisfactorily but in the field fluctuations of temperature, deposition of moisture on the balance parts with consequent liability to sticking of the suspended systems, vibration of the beams due to wind and other causes, all render photographic recording with this type of balance and protecting tent rather uncertain and after a continued trial we discarded it in favour of visual observation at night.

The protecting tent or hut provided with the balance is circular in section and is made in two parts readily clamped together. It is provided with three windows situated at the N., 120° and 240° positions respectively and as the tent is only three feet in diameter it is possible to read the balance scales visually without opening the tent. The advantage of this is apparent as the balance is completely enclosed and protected from external influences during a series of readings but there are certain drawbacks inherent to the arrangement in the field :

(*a*) Frequently during the night the interior surface of the observation windows becomes so obscured by moisture that it is impossible to read the scales.

(*b*) The small diameter of the tent brings the shielding surface very near the balance and so renders protection from temperature changes, solar radiation, etc., possibly less than it ought to be. This may partly explain the difficulty of getting reliable results during the day.

(*c*) From the same cause the foot of the tent lies very near the levelling base screws of the balance and any vibration of the tent due to wind is thus readily communicated to the base of the balance and so to the suspended systems. As a result, during high wind, visual reading of the scales is made difficult and photographic recording uncertain.

These disadvantages would probably be largely overcome by enclosing the hut and balance in an outer tent, which would have to be of considerable size, but owing to the advisability of limiting the amount of material to be transported this plan was not adopted.

The great advantage of the circular type of tent lies in the ease with which it permits of the balance being transported from station to station without dismantling either the tent or the instrument. This is done by attaching the balance, the suspended systems and moving parts having been clamped, by means of two sets of hooks and rigging-screws to the interior of the tent and transporting the whole bodily on a specially constructed trolley to the next station where balance and tent are immediately set up. The saving in time and labour over the other method whereby the tent and balance are dismantled, transported in parts to the next station and reassembled, is

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considerable and we have found the arrangement work well in varied conditions of terrain and weather.

THE CALCULATION OF TERRAIN EFFECTS

As pointed out in a previous paper[1] the quantities obtained from the balance readings are the resultant values arising from (1) the departure of the earth from a truly spherical form—the so-called normal effect—easily calculated from Helmert's formula, (2) the variable manner of distribution of rocks of different specific gravity in the earth's crust, and (3) variations in level and superficial distribution of mass in the neighbourhood of the balance, more particularly the *terrain effect* caused by changes in level of the surface of the ground within a radius of 100 ft. from the balance. The method of evaluating the terrain effect has been frequently described. A good level, an accurately divided levelling staff and a tape graduated in feet and 200 ft. long are necessary. Depending on the nature of the terrain it is necessary to take levels in 8, 16, or 32 azimuths around circles with radii of 5 ft., 10 t., 15 ft., 20 ft., 30 ft., 50 ft., 100 ft., from the balance station. If the ground in the immediate vicinity of the station point is irregular it may be advisable to take levels around a circle of 2½ ft. radius. The levelling must be done accurately to $\frac{1}{100}$ ft., particularly for the circles of smaller radius, and from the levelling data so obtained the terrain effect is evaluated by the method of Schweydar[2], who gives coefficients calculated for measurements made in the metric system. The following coefficients, which have been carefully checked, were calculated for measurements made in feet from Schweydar's general formulae. They differ materially from the coefficients published in "The Eötvös Torsion Balance", L. Oertling, Ltd., London, and by Fordham[3], and to a lesser extent from those given by Shaw and Jones[4].

	I	II	III	IV	V	VI	VII	VIII	IX	X
	2½ ft.	5 ft.	5 ft.	10 ft.	15 ft.	20 ft.	30 ft.	50 ft.	100 ft.	200 ft.
U_{xz}	26.62	22.31	35.6	9.14	2.79	1.48	.916	.435	.142	.0315
U_{yz}	26.62	22.31	35.6	9.14	2.79	1.48	.916	.435	.142	.0315
U_A	23.2	38.2	49.8	27.1	13.24	10.11	9.19	7.27	4.34	1.81
U_{xy}	23.2	38.2	49.8	27.1	13.24	10.11	9.19	7.27	4.34	1.81

If levelling is begun on the 5-foot circle the coefficients to be used are those in columns III to X; if levels are taken on the 2½-foot, 5-foot, &c. circles the coefficients to be used are those in columns I, II, IV to X.

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 170.
[2] Schweydar, W., *Zeitschrift für Geophysik*, I Jahrgang 1924/25, Heft 3, pp. 81-89.
[3] 'Oil Finding by Geophysical Methods,' *Journ. Inst. Petrol. Tech.*, vol. xi, 1925, p. 156.
[4] *Loc. cit.*, pp. 281-282.

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In Schweydar's analysis of the terrain effect it is assumed that radial lines on the surface of the ground between two points on adjacent circles are straight. The terrain over which the survey was made is pasture with pronounced ridges and furrows of former cultivation. The furrows are in places about six inches deep and the horizontal distance from trough to crest is only about five feet. In many cases the assumption referred to above was not valid within the 5-foot circle. It was therefore considered advisable to compare the values for the terrain effect calculated from levellings in eight and in sixteen azimuths with and without the inclusion of levellings on the 2½-foot circle. The terrain effects so calculated at four stations are shown in the following table.

Station.	Gradient component.	First circle at 5 ft.		First circle at 2½ ft.	
		8 azimuths.	16 azimuths.	8 azimuths.	16 azimuths.
4	U_{xz}	+ 0.71	+ 0.53	+ 2.55	+ 2.57
	U_{yz}	+ 11.3	+10.9	+ 9.84	+ 9.47
6	U_{xz}	+ 2.49	+ 3.52	+ 2.56	+ 3.55
	U_{yz}	+15.04	+15.5	+13.81	+13.7
8	U_{xz}	+ 7.01	+ 6.72	+ 7.03	+ 6.46
	U_{yz}	−11.27	−10.05	−11.25	−10.40
5	U_{xz}	+ 3.81	+ 5.44	+ 3.83	+ 5.80
	U_{yz}	+ 5.16	+ 5.81	+ 6.50	+ 6.45

Bearing in mind that the furrows run almost due magnetic east and west we should expect the U_{xz} component to be more affected by levelling the 2½-foot circle than the U_{yz} component. This is illustrated by Station 4. At Station 6 it may be noted that the U_{yz} component is the more affected. In this case a drain channel about nine inches deep lay five feet west of the station point. The advisability of levelling stations 5 and 8 in sixteen azimuths is clearly shown by the figures in the table, but for these stations it was sufficient to commence levelling on the 5-foot circle. A further point may be noted with regard to the terrain. The material constituting the terrain is a marly, somewhat gravelly, drift which has a specific gravity of 1.66 when dry. When saturated with water after heavy rain it was found to have a specific gravity of 1.79.

The importance of accurate terrain corrections is strikingly illustrated by Figs. 2 and 3 (pp. 6, 7), which show respectively in graphical form the results before and after correction for terrain and normal effects.

NATURE AND RESULTS OF THE TEST

The nature of the test is indicated in Fig. 1. The Swynnerton

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(A). *Swynnerton Dyke. Line of traverse, looking east. The white tabs indicate stations.*

(B). *Swynnerton Dyke. Line of traverse, looking west. The white tabs indicate stations.*

To Face p. 4.

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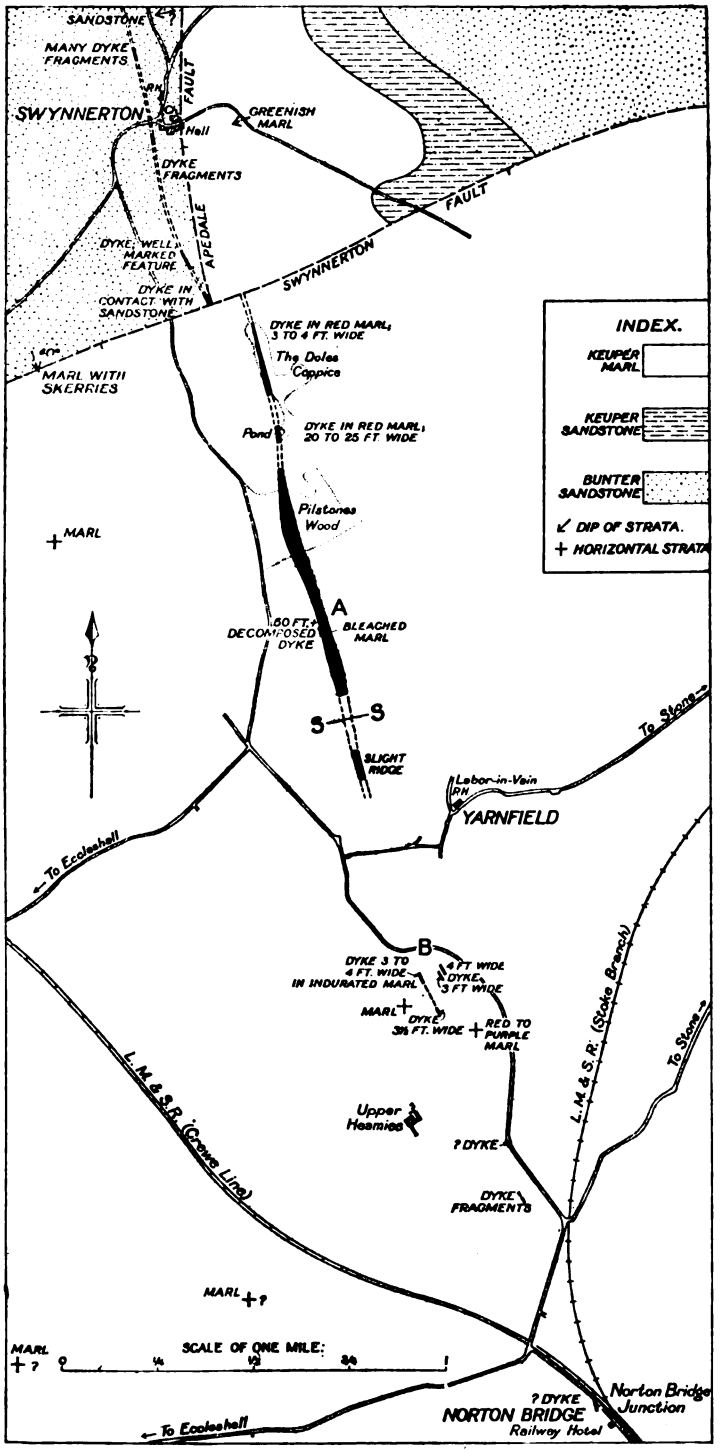

FIG. 1.—*Sketch-map showing the outcrop of the Swynnerton Dyke.*

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dyke[1] is a nepheline-basalt of post-Triassic age. Southwards from Swynnerton it has been traced practically continuously for a distance of one and a half miles. Thereafter its course lies through a flat drift-covered country for one mile, when it is again exposed in the hillslope half a mile south by west of Yarnfield. The traverse by torsion balance was made at right angles to the presumed course of the dyke through this drift-covered area at a position 2,000 ft. 35° to 40° north of west of the inn at Yarnfield. The line SS in Fig. 1 indicates the exact site in relation to the various exposures. The results plotted in Fig. 2 show the gradient components parallel to the line of traverse as calculated directly from the balance observations.

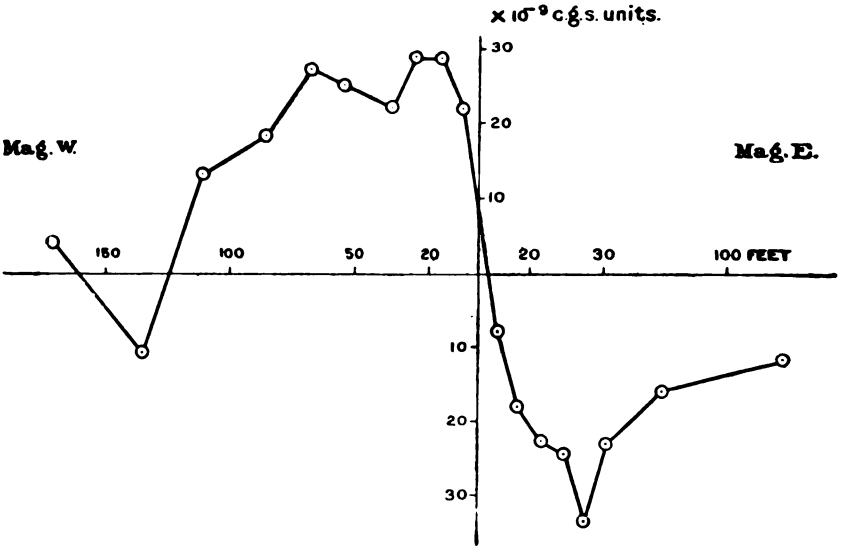

FIG. 2.—*Components of total gradients parallel to the line of traverse.*

After application of the normal and terrain corrections the residual components parallel to the line of traverse, which are due only to subterranean structure, fall on an almost smooth curve as shown in Fig. 3. The resultant residual gradients are represented in magnitude and direction by arrows in the plan, Fig. 4, from which we note that the average direction of the gradients is parallel to the line of traverse and therefore at right angles to the presumed course of the dyke. But the variation of the gradients is more clearly shown by the continuous curve of Fig. 3. The ordinates of this curve represent the values of the components of the gradient parallel to the line of traverse and the abscissae the distances between the stations. Positive ordinates indicate that the gradient-components[2] parallel

[1] Robertson, T., 'The Country between Stafford and Market Drayton' (*Mem. Geol. Surv.*), 1927, pp. 65-69.

[2] The gradient components perpendicular to the line of traverse are relatively very small and have not been considered. Significant results could have been obtained from them only if two or three short parallel traverses had been made.

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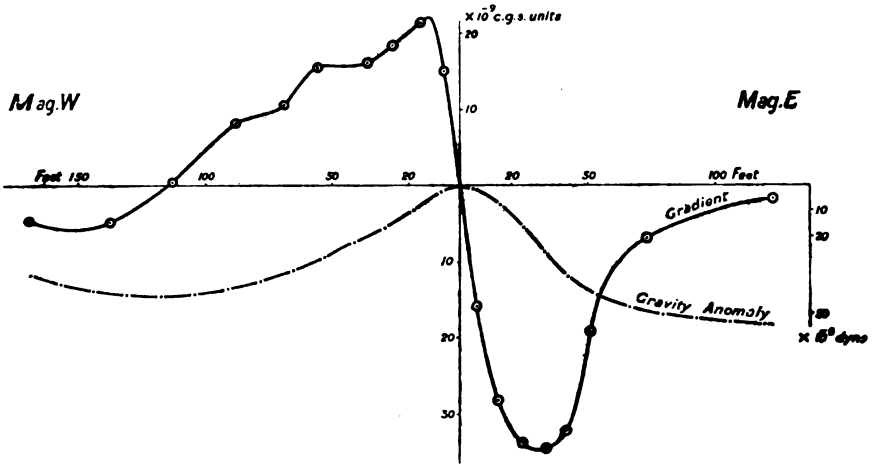

FIG. 3.—*Components of corrected gradients parallel to the line of traverse.*

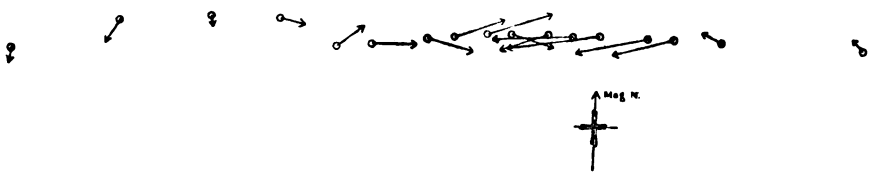

FIG. 4.—*Plan of gradients obtained in survey across the Swynnerton Dyke.* (*Scales:* (1) *Horizontal plane* 1 *cm.* = 26 *ft.*; (2) *of arrows* 1 *mm.* = 2.6 *E.*)

to the line of traverse are directed to the right, negative ordinates indicate that they are directed to the left. It will be observed that there is a point on the line of traverse towards which the gradients are directed, and that to the east and west of this point the magnitude of the gradients increases and decreases very rapidly. This indicates that a heavy mass of rock with abrupt east and west terminations exists approximately under the position of zero gradient. The actual increase in the force of gravity due to this heavy mass can be obtained by integration of the gradient curve, and is shown in Fig. 3 by the interrupted curve, the so-called gravity anomaly curve, from which it is apparent that the increase is approximately 50×10^{-6} dyne, that is, 1/20,000 dyne.

In addition to the gradients of gravity the balance observations also allow us to calculate the horizontal directing tendency (briefly H.D.T.) or curvature vector, and this quantity is usually plotted in plan along with the gradients. In the present case, however, in order to avoid a complicated diagram it is best to keep the plans separate. In Fig. 5 the small circles indicate station points and the lines through them represent the magnitude and direction of the H.D.T. at these points corrected for normal and terrain effects. The direction shows the direction of least curvature of the level surface at

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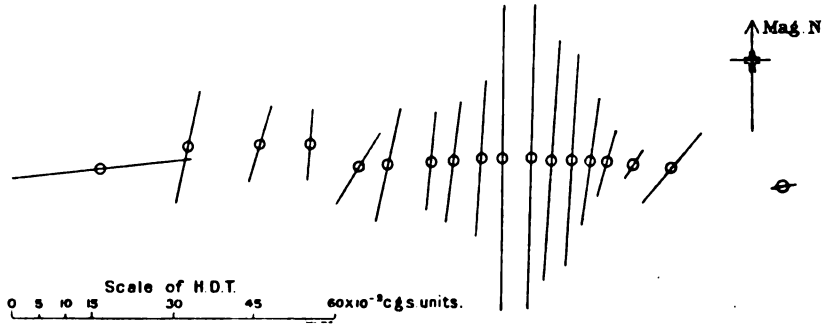

FIG. 5.—*Plan of residual H.D.T. obtained in the survey over the Swynnerton Dyke. For distances between stations see Figs.* 3 *and* 4.

the station and, from theory, this direction at points close to and over a dyke is parallel to the strike. The length of the line is proportional to the greatest difference in curvature of the level surface at each station. This maximum difference of curvature varies from station to station and is greatest at or nearly above the centre of the dyke. At or very near this point the gradient is zero.

The results plotted in Fig. 5 and in the gradient plan Fig. 4, when compared with the geological map, Fig. 1, show a series of curvature vectors (=H.D.T.) parallel to the known strike of the dyke and a

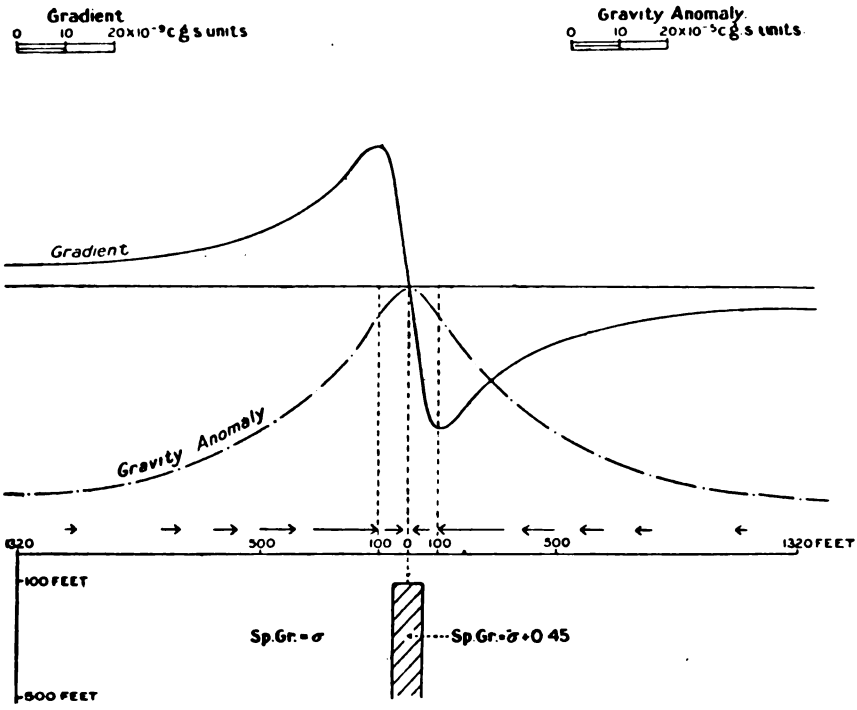

FIG. 6.—*Theoretical gradients for a vertical dyke.*

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series of gradients whose average direction is perpendicular to the curvature vectors and to the strike. Further, the striking increase in H.D.T. just at the position of reversal of rapidly varying gradients is additional verification of the existence beneath the surface of a heavy rock-mass with steep east and west terminations such as has already been indicated by the gradients.

INTERPRETATION OF THE RESULTS

In Fig. 6 is shown the curve of gradients calculated for a vertical dyke of width 100 ft. with its top 100 ft. below the centre of gravity of the balance. There is sufficient resemblance in general shape between this theoretical curve and the experimental gradient curve of Fig. 3 to indicate that the torsion balance has detected a dyke-like structure. The differences, however, are considerable and the main points of difference to be noted are (i) the greatest positive

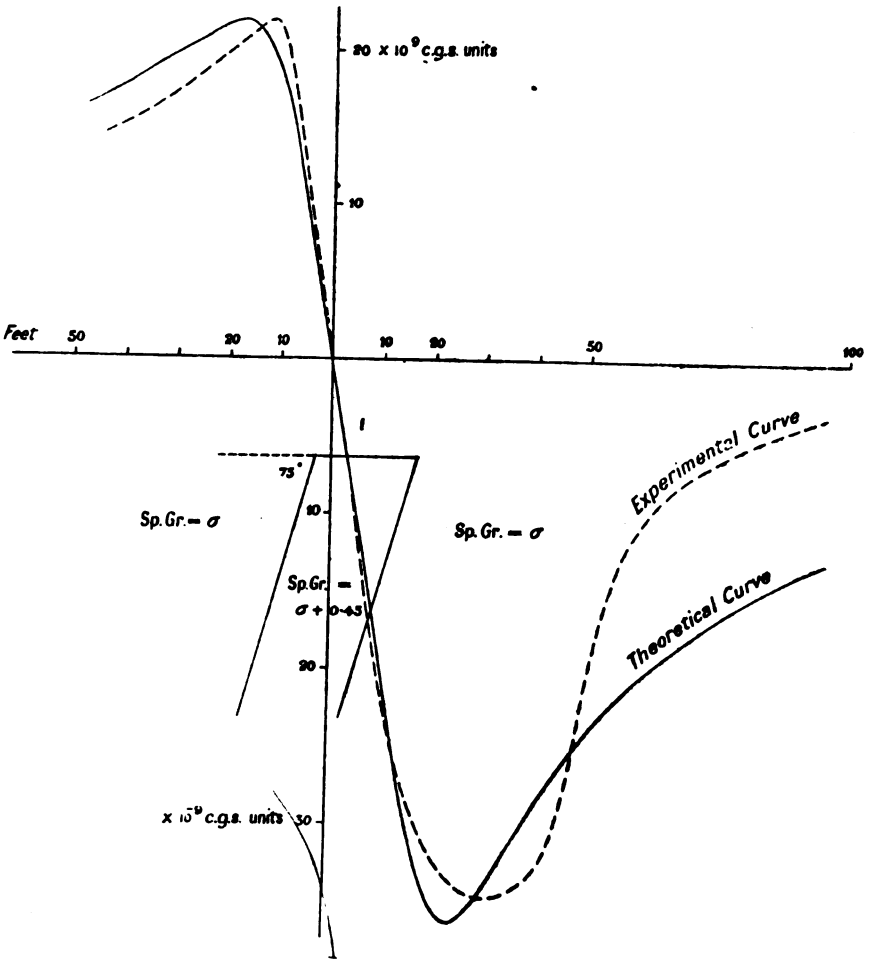

FIG. 7.—*Theoretical gradients for an inclined dyke and experimental results of actual survey.*

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gradient is much less numerically than the greatest negative one, and (ii) the gradients left of the maximum decrease more slowly than do the gradients right of the minimum. If the gradient curve for a dyke dipping at a high angle to the west be constructed (using the formula given below), a much closer correspondence to the experimental curve is obtained. The fact that the ratio of the maximum and minimum gradients is considerably different from unity means that the dyke deviates considerably from the vertical. In Fig. 7 the continuous line is the curve of gradients calculated for a dyke 20 ft. wide, depth of top 19 ft. beneath the centre of gravity of the balance, dip 75° W., and with a specific gravity 0.45 greater than the country rock ; the interrupted line is the experimental curve of Fig. 3. Correspondence is now so marked that it may be accepted that the survey has detected the existence beneath the covering of drift of a dyke whose width, depth, and dip are of the same order as those of the dyke shown in Fig. 7.

It may be noted from Fig. 5 that the H.D.T. retains a high value on the right of its maximum for a greater distance than on the left. This supplements the evidence of the gradients that the dip of the dyke is towards the west. The maximum H.D.T. for a dyke with the dimensions mentioned above is 56E, which is in good agreement with the highest value, 58.5E, found during the survey[1].

Determination of the specific gravity of the Swynnerton dyke from specimens gave values varying from 2.85 to 3.0. The country rock at the site of the survey is Keuper Marl, the specific gravity of which is not easily determined but is approximately 2.4 for wet marl. These figures give an average specific gravity difference of 0.52 between dyke and marl and if this be correct the depth given for the dyke is the least depth, that is the top is at least 16 ft. beneath the surface.

The differences between the two curves of Fig. 7 can be explained as the result of irregularities of the surface of the dyke and marl beneath the drift.

The geological evidence and the results obtained with the torsion balance are summarised in the table below. The localities refer to Fig. 1. The position at which the gradient is zero and the H.D.T. maximum lies within the dotted boundaries shown in Fig. 1. The deduced centre of the dyke also lies within the same boundaries.

Swynnerton Dyke

At Pilstones Wood.	At locality A.	At SS.	At locality B.
Width = 200 ft.	Width = 60 ft.	Width = approx. 20 ft. Depth beneath surface = approx. 16 ft. Dip = approx. 75° W.	Three branches whose aggregate width is 11 ft. Dip about 70° W.

[1] The highest value would probably be 60 to 62E.

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METHOD OF CALCULATING DEPTH, ETC., FOR A DYKE OR LODE.

In Fig. 8 let AB be the flat top of a parallel-sided dyke which stretches to a great distance in the horizontal direction perpendicular to AB and which also extends to a great depth.

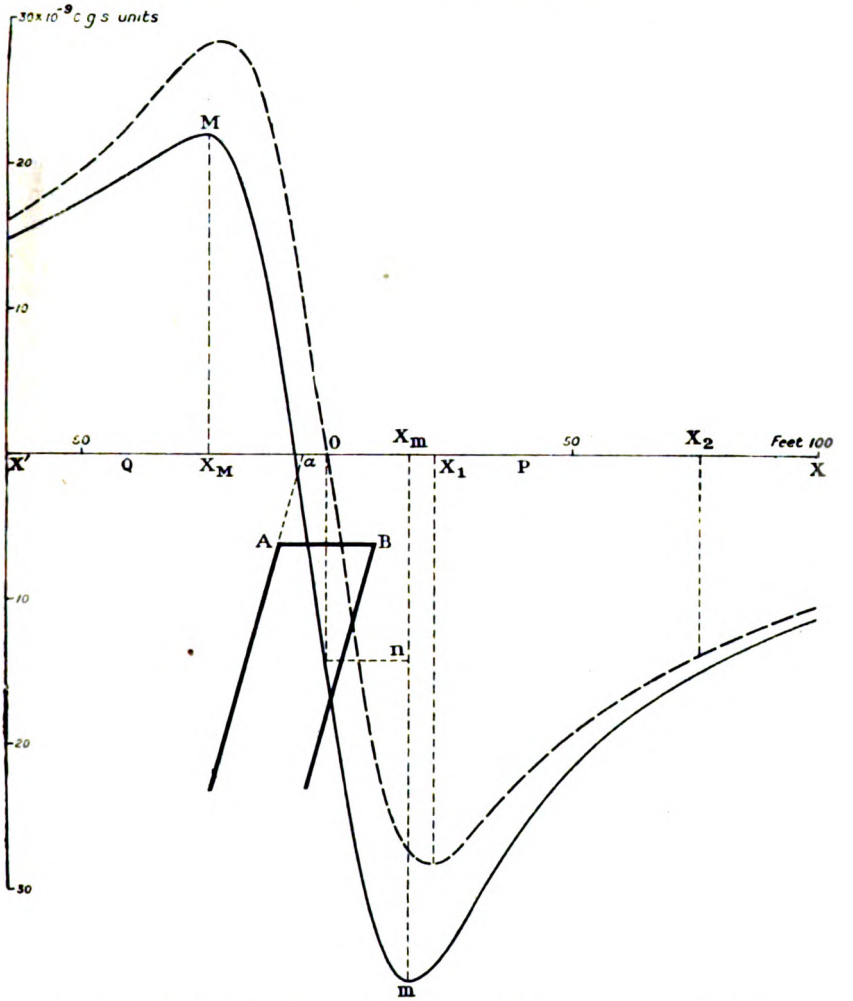

FIG. 8.—*Diagram to illustrate method of calculating depth, etc., of an inclined dyke or lode.*

Let α = angle made by the sides of the dyke with the positive direction X'X

$2l$ = width of top

d = depth of top

σ = difference of specific gravity between dyke and country rock

G = constant of gravitation = 66.6×10^{-9} c.g.s. units

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Then the gradient at any point P on X′X is given by

$$U_{xz}=G\sigma\left\{2\sin^2\alpha\log_e\frac{PB}{PA}-\sin 2\alpha\ (XPB-XPA)\right\}\ldots I$$

or, if the origin of co-ordinates is taken at O vertically above the middle line of the top of the dyke, by

$$U_{xz}=G\sigma\left\{\sin^2\alpha\log_e\frac{(x-l)^2+d^2}{(x+l)^2+d^2}+\sin 2\alpha\ \tan^{-1}\frac{2dl}{x^2+d^2-l^2}\right\}\ldots II$$

The expression I for the gradient is used in conjunction with a scale diagram of the dyke, the lengths PB, PA and the angles XPB, XPA being measured from the diagram and the values substituted in I. In working out the value of the gradient it is to be remembered that the logarithm term is a Naperian logarithm and that the values of the angles must be converted from degrees into radians. The formula for the gradient when logarithms to base 10 are used and when angles are measured in degrees is

$$U_{xz}=G\sigma\left\{4.605\ \sin^2\alpha\ \log_{10}\frac{PB}{PA}-\frac{\sin 2\alpha}{57.296}\ (XPB-XPA)\right\}\ldots III$$

The expression II is used to determine general relations between the depth, width, and dip of any dyke. By equating the derivative of this expression to zero we can obtain the positions X_M and X_m at which the gradient is maximum and minimum, and also we find the general result that

$$X_MX_m=2\sqrt{l^2+d^2}\ \operatorname{cosec}^2\alpha\quad\ldots\quad\ldots\quad\ldots\quad\ldots\quad IV$$

By substituting in II the values of x corresponding to X_M and X_m the maximum and minimum values of the gradient are found, and further, their sum is found to be

$$X_MM+X_mm=G\sigma\sin 2\alpha\tan^{-1}\frac{2dl}{d^2-l^2}\quad\ldots\quad\ldots\quad V$$

The expression on the right-hand side of V is from II easily seen to be the value of the gradient at O and we have therefore the general result that the algebraic sum of the maximum and minimum gradients is equal to the gradient at the point vertically above the middle of the top of the dyke. Therefore, to find the middle point of the dyke from an experimental gradient curve lay off on mX_m mn equal to X_MM. Then the horizontal line through n will cut the gradient curve in the vertical through the middle point of the top of the dyke.

The following method of obtaining a complete solution to the dyke problem is due to Nikiforov[1].

In the expression II for the value of the gradient let

$$f(x)=G\sigma\ \sin^2\alpha\ \log\frac{(x-l)^2+d^2}{(x+l)^2+d^2}$$

and

$$F(x)=G\sigma\ \sin 2\alpha\ \tan^{-1}\frac{2dl}{x^2+d^2-l^2}$$

[1] 'Physical Principles of the Gravitational Method of Prospecting,' *Bull. Inst. Pract. Geophys., Leningrad*, vol. 1, 1925, pp. 235-239.

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Then

$$\text{Gradient} = U_{xz}\ (x) = f(x) + F(x)$$

But

$$f(x) = -f(-x) \text{ and } F(x) = F(-x)$$

Therefore

$$U_{xz}\ (x) - U_{xz}(-x) = 2f(x) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{VI}$$

and

$$U_{xz}(x) + U_{xz}(-x) = 2\,F(x) \quad \ldots \quad \ldots \quad \ldots \quad \ldots \quad \text{VII}$$

Having obtained the middle point of the dyke as shown above we can, by means of equations VI and VII, break down the experimental curve into two parts corresponding to f(x) and F(x). To obtain the logarithmic part f(x) we make use of equation VI. From the algebraic value of the gradient at any point P subtract the algebraic value at the corresponding point Q, which is an equal distance on the other side of O. Divide the result by 2 and plot the value against P and Q. In this way a curve (the broken curve of Fig. 8) representing the expression

$$G\sigma \sin^2\alpha \log \frac{(x-l)^2+d^2}{(x+l)^2+d^2}$$

is obtained. This expression gives the value of the gradient due to a vertical dyke of width 2l and depth d, and is maximum or minimum when

$$x = OX_1 = \sqrt{d^2 + l^2} \quad \ldots \quad \ldots \quad \ldots \quad \text{VIII}$$

The distance OX_1 is determined from the experimental results. Equation VIII and equation IV are now available for determination of l, d, and α. To obtain a third equation Nikiforov determines the distance OX_2 at which f(x) is half its maximum value. Then the following equation holds.

$$\left[\frac{(OX_2 + l)^2 + d^2}{(OX_2 - l)^2 + d^2}\right]^2 = \frac{OX_1 + l}{OX_1 - l}$$

This simplifies to

$$\left.\begin{aligned} l &= \sqrt{A\,(2OX_1 - A)} \\ \text{where} \\ A &= \frac{\overline{OX_1}^2 + \overline{OX_2}^2}{2\,OX_2} \end{aligned}\right\} \quad \ldots \quad \ldots \quad \ldots \quad \text{IX}$$

In equation IX the numerical values of OX_1 and OX_2 are substituted and l is then calculated. The depth is next determined from equation VIII, and finally, the angle from equation IV.

In an ordinary field survey it is unlikely that the point X_2 can be determined accurately since effects due to subterranean topography and general structure will affect its position considerably. The point on the steep part of the curve f(x) between O and X_1 at which the gradient is half the maximum may then be determined and the abscissae of this point used in equation IX in place of OX_2.

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The value of l so determined will serve as a basis for constructing one or two gradient curves by means of formula I, the values of d and α being of course related to any arbitrary value of l by the equations IV and VIII. The values of l, d and α which give the gradient curve most comparable with the experimental one may then be taken as approximations to the real values for the dyke.

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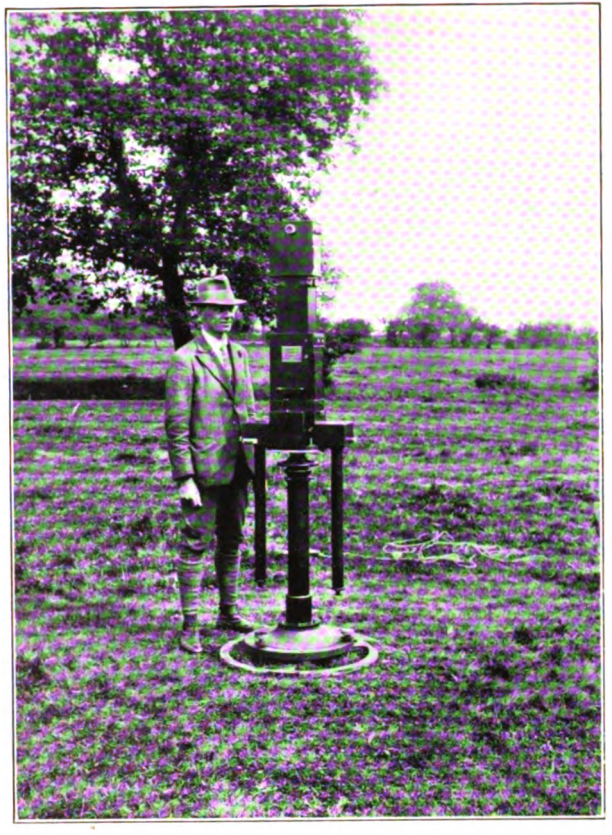
To Face p. 14.



(A). *The Eötvös Torsion Balance.*

(B). *The Eötvös Torsion Balance, showing protecting hut and method of visual reading.*

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II.—THE COCKERMOUTH LAVAS, CUMBERLAND—A CARBONIFEROUS VOLCANIC EPISODE

By T. Eastwood, A.R.C.Sc.

Text-figure 1.

Most geologists are familiar with the maps of the Lake District, which show Skiddaw Slates flanked by igneous rocks referred to the Borrowdale volcanic episode of the Ordovician period. These in turn are ringed about by Carboniferous strata. The Ordovician age of the igneous rocks, with the possible exception of those of Eycott, has been accepted without question.

While surveying the Cockermouth area, however, the writer was struck by the fact that a series of basaltic lavas, previously mapped as Borrowdales, were underlain by a conglomerate unlike anything in the Skiddaw or Borrowdale sequence. Apart from the fact that the lavas were more basic than usual and much less disturbed than is commonly the case in the Lake District, there seemed no reason why, in the absence of normal types of Borrowdale lavas here, they should not belong to that group, especially as the conglomerate does not there appear to contain any of the easily recognised Borrowdale types.

Previous surveyors, Clifton Ward and Goodchild, had noticed the presence of the conglomerate and recorded it as the basal member of the Carboniferous. To account, however, for its position between the Skiddaw Slates and the lavas they either introduced some frankly theoretical faults or ignored it altogether.

Examination in the field, especially between Wood Hall and Redmain to the north of Cockermouth (Fig. 1), makes it perfectly clear that the lavas rest in a normal fashion on the conglomerate. The actual junction is never visible, but in several cases the obscured gap is only about 5 ft. in thickness, and both rocks are seen to make V-shaped outcrops in the ravines of the steep tributaries on the north-west bank of the Derwent. The contact between the conglomerate and the underlying Skiddaw Slate is likewise never actually exposed, but here again the obscured portion is but a few feet in width.

One of the most noteworthy constituents of the conglomerate is Latterbarrow Sandstone—a rock generally acknowledged as being at the summit of the Skiddavian and actually occuring at one place beneath the conglomerate. It follows, therefore, that if the lavas are a rather peculiar type of Borrowdales, then the conglomerate, which obviously precedes them, must be of early Borrowdale age and must mark a period of considerable erosion. This, in fact, was the first assumption pending a petrological examination of the lavas.

On Dr. H. H. Thomas announcing the presence of olivine a

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further and more comprehensive suite was submitted, as the possibility of their not being of Ordovician age was then realised. They were either a new type of Borrowdales, or, by a freak of nature, the Borrowdales were absent and a suite of volcanic rocks of Old Red Sandstone or Carboniferous age occurred here and nowhere else in the Lake District between the Skiddaw Slates and the Carboniferous Limestone.

Since Clifton Ward and Goodchild were familiar with the Borrowdale group and had mapped them, probably from east to west, into the area in question, it was evident that further work was required to extend the knowledge derived from the limited outcrops examined in the south-eastern corner of the One-inch Sheet 22 (Maryport) and the south-western margin of Sheet 23 (Cockermouth) (Old Series Geol. 101 N.W. and 101 N.E.).

Acting upon instructions, the ground to the north-east was examined and the range of the basaltic lavas has been found to extend from the west of Cockermouth, and Redmain north of that town, to the Keswick-Bothel road near Bothelcrags—a total distance of seven miles (Fig. 1)—and their relationship to the overlying limestones has been more clearly established.

The Conglomerate.—Although this communication mainly concerns the lavas, a few lines are necessary to describe the conglomerate which occurs immediately below them and is used as a lower limit in determining their horizon.

The best exposures are in the neighbourhood of Wood Hall, north of Cockermouth, where about 50 ft. is seen, though the total thickness is probably nearer double that amount. The formation consists of rock fragments up to 3 or 4 in. in diameter, mainly rounded but frequently subangular, set in a sandy matrix consolidated by a limy cement and often stained red. Although bedding of the coarser fragments is not apparent, posts of such material alternate with beds of coarse, buff, and occasionally flaggy sandstone, and in places with red sandy marl indistinguishable from Triassic marls. In the upper part of the formation, as seen in a stream in East Wood, 550 yds. N.E. of Wood Hall, thin bands of breccia-conglomerate alternate with red sandy marl altered to a green colour in places along the contacts and joints. Some of the rock fragments can be matched undoubtedly with the underlying formation, but others, mostly decomposed and of igneous origin, are at present unfamiliar. Pebbles of white vein quartz are fairly common, but the most important type is a red, purple, or grey quartzitic sandstone (not unlike some of those encountered in the Bunter of the Midlands) which is referred to the Latterbarrow Sandstone. Dr. Smith and Mr. Hollingworth confirm this identification. Some of the other rock fragments recall the sandy shales of the Skiddaw Slates, while another common constituent is a pinkish rhyolite. Dark rhyolite occurs sparingly. In the Wood Hall area, typical Borrowdale ashes are conspicuous by their absence, but farther to the north-east greenish tuffs occur very sparingly as pebbles. In this connexion it is interesting to recall the

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the experience of Clifton Ward[1] who found no Borrowdale rocks in the conglomerate on Mell Fell though they are common at Hutton, two miles farther east.

The conglomerate has not been found south-west of the Cockermouth-Carlisle road but appears immediately east of that road and at intervals along the north-west bank of the Derwent for several miles (Fig. 1). In addition to that in the neighbourhood of Wood Hall, the exposure in the gill below Redmain is worthy of notice, especially since the Latterbarrow Sandstone there occurs *in situ* below the conglomerate. North-east of Redmain exposures are poor, on account of Glacial drift, but the rock is again seen in the lower part of Park Wood, along Blumer Beck, about three quarters of a mile south-west of Sunderland. From that point it has not been located until the John Peel barytes mine at Ruthwaite is reached, where trial shafts, to the east of the main vein, passed through a pebbly sandstone with bands of conglomerate. It also occurs in typical form in the stream immediately south of Uldale, to the east of the road leading to Over Water. In this eastern area the conglomerate must rest on the Borrowdale rocks which crop out to the south.

The Lavas.—The lavas are usually fine-grained, dark, blue-grey compact rocks. Minute amygdales are frequently present and these are in places sufficiently large and numerous to give the rock a scoriaceous appearance, especially at the top and bottom of the flows, although in some cases the distribution of the clinker-like rock is haphazard. The vesicles are frequently filled with calcite, agate or quartz, and when the rock is markedly slaggy these are stained bright green. Although the vesicles are frequently distorted they show very little evidence of linear structure due to flow. The compact or but slightly vesicular rock is commonest in occurrence. Amygdaloidal rock is particularly well developed about a quarter of a mile north-east of Wood Hall.

The following notes on the petrological characters have been supplied by Dr. H. H. Thomas. Numbers in square brackets refer to rock slices in the Survey Collection.

"The lavas of this group are remarkably consistent, showing only slight variations in composition and structure. In their compact or less decomposed portion they are dark grey and microcrystalline, with occasional porphyritic felspars up to 1 cm. in greatest length [E.13975]. As a group they fall between micro- and macro-porphyritic basalts and by the scarcity of porphyritic felspars may be classed as a somewhat coarse variety of Dalmeny type.

"Their microscopic structure is generally that of micro-porphyritic basalt in which abundant small pseudomorphs after olivine are the dominant feature. The rest of the rock consists of granular to sub-ophitic augite and a plexus of labradorite laths that involve grains of augite and finely divided magnetite. The felspar laths frequently show a poorly developed fluxional arrangement.

[1] 'On the Physical History of the English Lake District with Notes on the Possible Subdivision of the Skiddaw Slates,' *Geol. Mag.*, 1879, p. 57. See also 'The Geology of the Northern Part of the English Lake District' (*Mem. Geol. Surv.*), 1876, p. 47.

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'Occasional porphyritic felspars of the composition of bytownite can be observed but they are rare [E.13975].

"Some of the rocks, possibly the interior of the thicker flows, have a more doleritic aspect. In these [E.13976] the augite is more definitely ophitic. In other cases, where fine-grained, the rocks might be described as tholeiites [E.13898]. They contain original glass and an abundance of chlorophaeite, a mineral common in the Carboniferous intrusions of the Lothians.

"Olivine in these lavas is abundant, generally pseudomorphed by the usual limonitic and chloritic secondary products, but occasional remnants of olivine are preserved in fresh condition [E.13898].

"The augite is quite frequently fresh but when decomposed passes into carbonates.

"Felspars do not appear to have been albitized to any considerable extent but have been involved in a general replacement by carbonates.

"As a suite they are quite unlike not only any Borrowdale volcanic rocks with which I am acquainted but also any Lower Palaeozoic rocks that I have met with. They can be matched amongst the Lower Carboniferous lavas of Fifeshire and there is no doubt that their chief likeness is to the Carboniferous lavas of Scotland and to some of the Carboniferous intrusions of the north of England."

Although the lavas form several flows, of which there are four or five near Wood Hall with an aggregate thickness of over 300 ft., no tuffs have been noticed, though it is interesting to record that a roughly lenticular mass of red and green marl or 'bole-like' material, interspersed with lumps of very rotten amygdaloidal rock, occurs between two flows in the stream north-east of Wood Hall.

Rectangular jointing is common in the compact rock but there is no development of the columnar jointing usually associated with this class of lava.

The general distribution of the lavas is shown in the sketch map (Fig. 1). The following remarks apply to particular occurrences.

To the south-west the outcrop of the lavas is terminated by a fault about half a mile east of Brigham. In this area exposures are poor owing to the presence of Glacial drift, but both the amygdaloidal and compact types may be seen between Scales, East House and the River Derwent.

North of the Derwent, drift masks the outcrop as far east as the Carlisle-Cockermouth road; but from thence to the north-east exposures are frequent and the outcrop is almost continuous, although shifted by faults. Some of the best exposures are in the vicinity of Wood Hall, just over a mile north of Cockermouth, the stream section a quarter of a mile north-east of that mansion being particularly fine. In this area the basalt is faulted against the 7th or Bottom Limestone. From Redmain to some distance beyond that hamlet, this fault probably cuts out the basalt and brings the 7th Limestone against the conglomerate, though farther to the north-east the basalt reappears whilst the conglomerate is cut out by the fault. In this part of the outcrop exposures are particularly good in the stream flowing into the Derwent from Blindcrake. Here gently dipping shales and thin limestones, which occur at the bottom of the Limestone Series, are seen within 30 ft. of the basalt.

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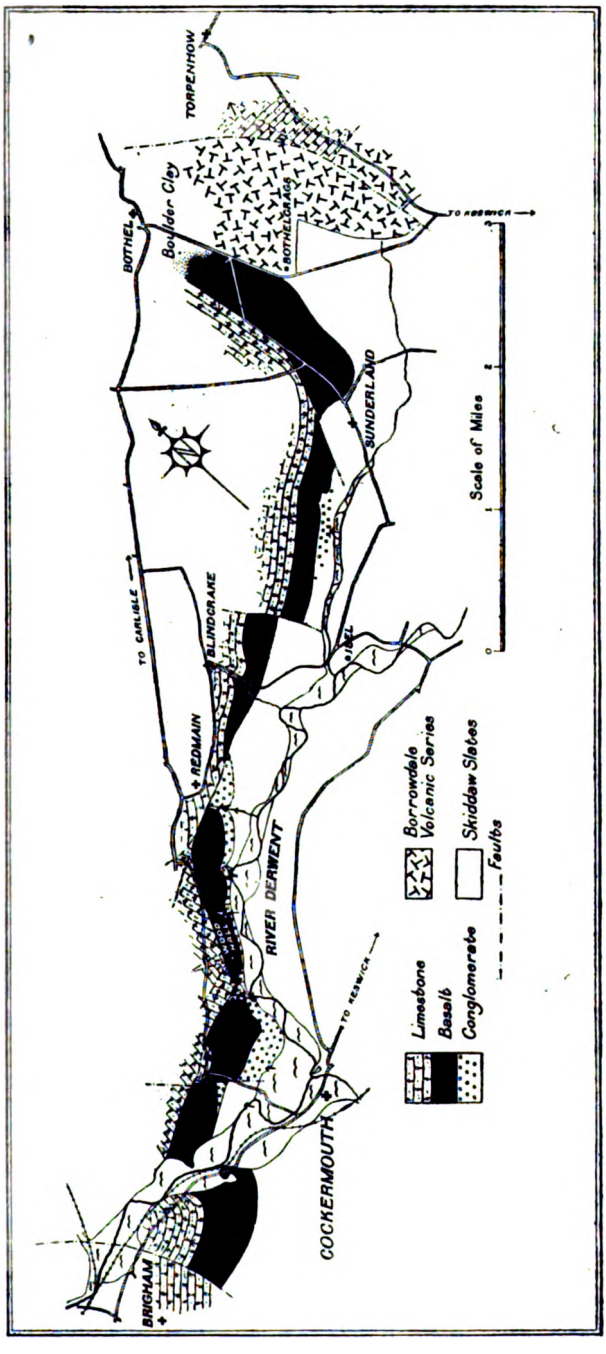

FIG. 1.—*Sketch-map to show the Distribution of the Cockermouth Lavas.*

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About half a mile east of Blindcrake the outcrop of the lavas is shifted to the south by a dip-fault, limestone on the east being brought within a few feet of exposures of basalt. Thence towards Sunderland exposures are common, the basalt ranging through Park Wood accompanied by a parallel outcrop of limestones in the higher ground; while the conglomerate and the Skiddaw Slates may be seen in or near the stream at the bottom of the wood.

About the village of Sunderland the outcrop is obscured by thick Glacial drift and there may be some faulting as the ground is locally of lower relief than one would expect from basalt; but from the Methodist Chapel to Bothelcrags there are several small quarries in the rock, which is here seldom markedly vesicular. The best quarry is that on the south-west side of the road about a quarter of a mile north-west of Bothelcrags, while a coarser variety forms a small knoll about half a mile south of Bothel.

It is evident, therefore, that the lavas can be traced with certainty from between Brigham and Cockermouth to the Bothel-Keswick road at Bothelcrags. In this stretch of ground, rocks referable to the Borrowdale Volcanic Group are absent, the conglomerate below the lavas being in contact with the Skiddaw Slates, of which the highest member is exposed in one place only, namely Redmain Gill.

In the intensively explored iron-ore field to the south-west no trace of the lavas has been found, and this was one of the reasons why hesitation was at first felt in assigning them to the Carboniferous period.

Near Bothelcrags the Keswick road may be taken as the dividing line between the Cockermouth lavas and the Borrowdale Volcanic Group, for typical andesitic Borrowdale rocks and the porphyritic Eycott types, both devoid of olivine, are exposed north-east of the road, whilst quarries in the basalt abut on the road on the south-west. Unless the lavas die out abruptly there must be a fault along the road, but the adjacent ground awaits detailed mapping. Whether faulted or not, it is a fact that traverses have failed to reveal any outcrops of the Cockermouth basalt beyond this line, and at Uldale farther east there is no room between the outcrops of the conglomerate and the Limestone Measures for any intervening basalt. We must assume, then, that the lavas either die out rather abruptly, or are overlapped, as we proceed from west to east. The latter seems the more probable.

To produce a mass of rock some 300 ft. in thickness, and cropping out over a distance of seven miles, implies more than a trifling outbreak of vulcanicity. The mode of occurrence of the basalt, as flows with slaggy tops and bottoms, precludes the idea of intrusion; while the absence of pillow structure suggests an outpouring on land. Quiet extrusion is indicated by the apparent absence of ashes, and the presence of 'bole' suggests some interval between the flows. Where the volcanic pipe or fissure was situated—and there may have been more than one—we do not know. Clifton Ward[1] records

[1] 'On the Physical History of the English Lake District, etc.,' *Geol. Mag.*, 1879, p. 58.

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small bosses of basalt penetrating the Carboniferous conglomerate near Mell Fell Farm north-west of Ullswater. In our district the only basalt dyke encountered, and that only 5 ft. in thickness, occurs in the Skiddaw Slates immediately below the conglomerate in the bank of the Derwent below Wood Hall. This is too small to account for such a large outpouring in the vicinity, but may be a dyke connected with a large concealed pipe. On the other hand, it is possible that the place of origin is now buried beneath the Solway, for it is suggestive that similar rocks to those of Cockermouth should occur in the Isle of Man[1] and along the English-Scottish Border.

Age of the Lavas.—Whilst the age of the basalt cannot be definitely settled in the absence of fossil horizons occurring immediately above and below, certain factors make it probable that we are dealing with an outbreak of vulcanicity in the earlier part of the Carboniferous sequence of this district. The limestone that occurs above, and with the same strike and order of dip as the lavas, is the Seventh Limestone of the West Cumberland sequence and belongs to S_2 horizon of Vaughan's classification.[2] The conglomerate that occurs below the basalt is almost identical in appearance with that of Mell Fell, the age of which is regarded by some observers as Carboniferous[3] while others claim it to be Old Red Sandstone.[4] The earliest possible age, on stratigraphical grounds, for our lavas, is therefore Old Red Sandstone (probably the later part), and the latest age Carboniferous Limestone (early S).

The Borrowdale lavas consist largely of rhyolites and andesites and, although some are more basic, olivine is either rare[5] or absent[6]. Our lavas on the other hand are rich in olivine and, according to Dr. Thomas, unlike older Palaeozoic lavas but very similar to Scottish lavas of Carboniferous age.

Prof. Garwood[7] has recently found a lava, identical with those of Cockermouth, near Kershope Foot, on the borders of Cumberland and Dumfriesshire. This occurs in the Limestone Series and is overlain by a limestone with *Nematophyllum minus*, a fossil characteristic of our Seventh Limestone.

The Cockermouth lavas, not only the compact type, but also the scoriaceous variety and the 'bole', may be also matched perfectly with that of Little Wenlock, Shropshire, which occurs

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[1] See 'The Geology of the Isle of Man' (*Mem. Geol. Surv.*), 1903, p. 226.

[2] See Edmonds, C., 'The Carboniferous Limestone Series of West Cumberland,' *Geol. Mag.*, 1922, pp. 74-83 and 117-131.

[3] Ward, J. Clifton, *op. cit.* See also J. E. Marr, 'The Geology of the Lake District,' *Camb. Univ. Press*, 1916, p. 113.

[4] Green, J. F. N., 'The Mell Fell Conglomerate,' *Proc. Geol. Assoc.*, vol. xxix, 1918, pp. 117-125.

[5] Ward, J. Clifton, 'The Geology of the Northern Part of the English Lake District' (*Mem. Geol. Surv.*), 1876, p. 20. See also *Monthly Microscopical Journ.*, vol. xvii, 1877, pp. 239-246.

[6] Harker, A., 'The Ancient Lavas of the English Lake District,' *The Naturalist*, 1891, p. 145; see also *Proc. Yorks. Geol. & Polytechnic Soc.*, vol. xiv, 1902, p. 487.

[7] To whom thanks are due for allowing publication of this fact.

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as a flow in beds of D_2 age and was recently described by Mr. R. W. Pocock[1].

On petrological and on stratigraphical grounds, therefore, there is every probability that the lavas cropping out between Bothel and Brigham, which we designate the 'Cockermouth Lavas', belong to the Carboniferous Limestone Series.

Vulcanicity in Other Areas.—Although hitherto unsuspected in West Cumberland, volcanic episodes in the Carboniferous Limestone sequence are of common occurrence elsewhere in Britain. In Scotland they are particularly common[2], and similar basalts to those of Cockermouth occur frequently in the Calciferous Sandstone Series[3].

Those on the English side of the Border have already been noticed, and they appear to continue through Dumfriesshire to Kirkcudbrightshire[4], and also occur in Roxburghshire.

To the south of our area the lavas of Derbyshire[5] have long been known and the work of Dr. T. F. Sibly[6] shows that they belong to a D_1 horizon. Those of Shropshire [*op. cit.*] are higher in the sequence, being of D_2 age, while, continuing southwards, we come to the occurrences in the Bristol district[7] lower in the succession and occurring between the horizons Z and C.

In most cases the lavas are associated with tuffs. In West Cumberland no tuffs have been found, but farther north tuffs occur in association with the basalt in the Penton-Kershope Foot area on the English side of the Border.

The Cockermouth lavas therefore form an interesting link between the English and Scottish occurrences, and though these effusions are not confined to any one particular horizon in the Carboniferous Limestone sequence they indicate widespread vulcanicity during that period.

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[1] 'The Basalt of Little Wenlock (Shropshire),' 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, Appendix I, pp. 140-156.

[2] Geikie, A., 'The Ancient Volcanoes of Great Britain,' London, 1897, vol. ii.

[3] 'The Geology of Central and Western Fife and Kinross-shire' (*Mem. Geol. Surv.*), 1900, pp. 53, 54. See also 'The Geology of the Glasgow District' (*Mem. Geol. Surv.*), ed.2, 1925, pp. 135-149, 178.

[4] 'Explanation of Sheet 5' (*Mem. Geol. Surv.*), 1896, pp. 28-29. For those of Liddesdale see Geikie, A., *op. cit.*, vol. i, pp. 475-477. A rock similar to that of Cockermouth was described from Stichill, near Kelso, by J. J. H. Teall, 'British Petrography,' 1888, p. 197, and *Geol. Mag.*, 1883, pp. 100, 258, 260.

[5] Arnold Bemrose, H. H., 'The Toadstones of Derbyshire: their Field Relations and Petrography,' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, pp. 241-281. See also C. B. Wedd, in 'The Geology of the Northern Part of the Derbyshire Coalfield' (*Mem. Geol. Surv.*), 1913, pp. 22-25.

[6] 'The Faunal Succession in the Carboniferous Limestone of the Midland Area,' *Quart. Journ. Geol. Soc.*, vol. lxiv, 1908, p. 39.

[7] Morgan, C. L., and S. H. Reynolds, 'The Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 137. Also S. H. Reynolds in 'Geology in the Field,' *Geol. Assoc.*, 1910, pp. 322-4; and 'Further Work on the Igneous Rocks associated with the Carboniferous Limestone of the Bristol District,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1917, p. 23.

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III.—THE ORIGIN OF CUMBERLAND HAEMATITE (1).—By E. E. L. Dixon, A.R.C.Sc., B.Sc.

Text-figure 1.

HAEMATITE-VEINS IN THE SKIDDAW SLATES

Haematite occurs in Cumberland chiefly in limestones, the ore-bodies in the Carboniferous Limestone being well-known and of great commercial importance. It is also found, however, in non-calcareous rocks, and of these occurrences the most important are the veins in the Skiddaw Slate of Kelton Fell and Knock Murton on the edge of the fells, east of Whitehaven. From these, though now practically exhausted and no longer worked, many thousand tons of ore have been raised by Messrs. Wm. Baird and Co., to whose late manager, Mr. Wm. Casson, our thanks are due for much valuable information about the surface-position and underground extent and character of the veins. In conjunction with the mapping of the various subdivisions of the Skiddaw Slate that form the country-rock, these details have revealed some of the conditions favouring ore-deposition in that formation.

In this district the Skiddaw Slate consists of the following groups in descending order[1]:—

4. Mosser Slates
3. Loweswater Flags
2. Kirkstile Slates
1. Blake Fell Mudstones

The groups of importance in the present connexion are the Kirkstile Slates and the Loweswater Flags, the former a band of soft dark slates practically devoid of sandstones, whereas the flag-group comprises innumerable alternations of hard sandstones and thin slates.

As is well known, the structure of the Skiddaw Slate of the Lake District is a great anticline complicated by much minor folding. South-west of Loweswater, however, the outcrop of the flag-group in the northern limb is comparatively simple, the beds dipping N.N.W. fairly steadily at 70° or more. Between Knock Murton and Keltonfell Top these rocks are crossed by two series of tear-faults, running approximately N.W.—S.E. and N.—S. respectively, and the fault-fissures, becoming the paths of mineralizing solutions, have given rise to the great majority of the haematite-veins. But, in places, the veins are so numerous as to suggest that under suitable conditions insignificant faults or mere joint-planes have been mineralized. The best example is afforded by the network of veins, immediately east of Keltonfell Top, that includes Veins

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, pp. 70-1.

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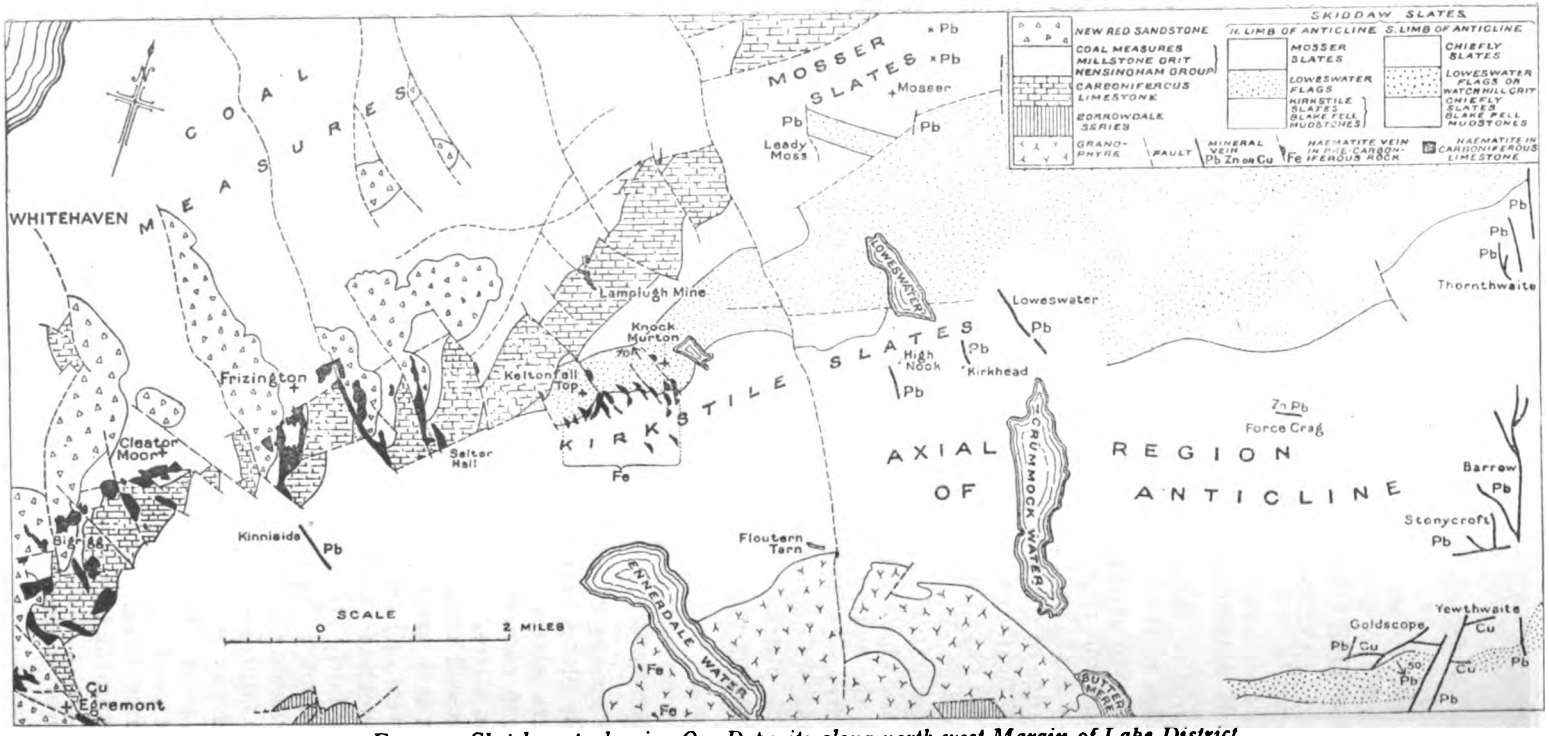

FIG. 1.—*Sketch-map showing Ore Deposits along north-west Margin of Lake District.*

The triangular area of Loweswater Flags S.W. of Loweswater should be stippled.

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1 and 2, B, D, G and H Veins, Vein North of Dyke, and the numerous splits off these veins. This view is supported by the fact, mentioned by Mr. Casson, that in several cases a vein could not be traced beyond the point where the ore thinned away and was lost, the cheeks apparently disappearing with the ore.

The ore has been deposited chiefly where the fissures cross the steeply-inclined junction of the Loweswater Flags with the Kirkstile Slates. It extends along the fissures well into the ground where the latter slates form both walls and, as a rule, to a much less extent in the opposite direction, *i.e.*, into the Loweswater Flags. On the map (Fig. 1) it will be seen that the veins are strung out along the junction; the greater development of ore in the adjacent slates than in the flags is most apparent in the above-mentioned network.

Nevertheless, it would appear that the fissures in the flags have been the channels for the mineralizing solutions, for bodies of ore have been deposited also where the two chief faults cross a band of mudstones in the upper part of the flag group, and, in many places along the outcrop in this district, joint-planes in this group have been encrusted with films of haematite or the sandstones along the planes have been permeated with the mineral.

Mineralizing solutions, whether ascending or descending, would be expected to follow the more open channels, as those in the flags may be presumed to have been, and instances of their behaviour in this way are well known[1]. Ore-deposition at or near a junction of dissimilar rocks also is a matter of common observation. Its significance in the present case is that when the outcrop of the Loweswater Flags is followed north-north-eastward from Knock Murton to Loweswater and Mosser the haematite-veins are lost, but a few small lead-veins appear in the slates not far below or above the Loweswater Flags or at the upper boundary of the flags. Within the limits of the ground re-surveyed in detail these veins are too few and small to be anything but suggestive. Traverses through the ground to the east as far as the Derwent valley (north-eastern edge of Fig. 1) show, however, that in the northern limb of the Skiddaw Slate anticline all the worked veins of lead and zinc occur near the junction of the Loweswater Flags with the underlying slates, and that in the southern limb the veins of copper and lead that have been worked at Goldscope, Yewthwaite and Brandlehow are similarly placed as regards a sandstone group that is either the Loweswater Flags or the Watch Hill Grit (a band in the Mosser Slates). Further, the Castlenook lead-mine lies near the top of the southern sandstone group. The country-rock of the remaining group of veins, those at Barrow and Stonycroft, has not been examined.

The outcrops of the non-ferrous veins are shown in Fig. 1 and

[1] *Cf.*, for example, the lead-zinc veins of the Minsterley district, described by Mr. T. C. F. Hall (see 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xxiii (Lead and Zinc Ores in the Pre-Carboniferous Rocks of West Shropshire and North Wales), 1922, and *Mining Mag.*, vol. xxvii, 1922, pp. 201-9). Usually, as in this instance, the ore occurs in the fissured rock, not in the adjacent argillaceous beds.

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have been taken from the Geological Survey maps and memoir[1]; the position of the sandstone group north-east of Goldscope is uncertain and the base is indicated by a dotted line.

The channels of the iron solutions through the Skiddaw Slate were similar, then, to those of the lead, zinc and copper solutions, and haematite was deposited not far beyond the limit of deposition of galena.[2]

As to the nature of these solutions, whether of lead, zinc and copper or of iron, conflicting views have long been, and still are, held. According to one theory the metallic compounds have been conveyed to their present position from overlying or possibly surrounding rocks, or from a continental drainage-basin, by descending meteoric waters. On the other view, their origin is magmatic and either deep-seated or volcanic, the transporting agent being ascending waters.

As regards the non-ferrous ores, the magmatic theory, though by no means universally held, is gaining ground,[3] but in the case of the haematite-veins it has received little favour, opinion being dominated by conclusions based on the ore-bodies in the Carboniferous Limestone, which are the best known and are by far the most important economically. Of these bodies it has been established beyond question that many have been deposited by downward-percolating waters, a fact which, taken in conjunction with the presence of a great thickness of red beds above and the general tendency of formations, unconformably overlain by such beds, themselves to be reddened from above, seemingly makes it unnecessary to look elsewhere than in the red beds for the source of the iron. Nevertheless, as Dr. B. Smith has shown[4], the explanation in the form that would make the period of ore-deposition earlier than, or contemporaneous with, that of the New Red Sandstone encounters great difficulties. But a great obstacle to all theories of downward percolation is that they fail to account for the occurrence of workable veins of haematite to considerable depths in Skiddaw Slate and other non-calcareous rocks. Owing to their restricted occurrence compared with that of the ore-bodies in the Carboniferous Limestone these veins have received little attention outside the district, but their importance in this connexion has been pointed out by J. D. Kendall, who in 1879 first suggested the deposition of the Cumberland haematites by magmatic waters[5] and has maintained it on many

[1] Eastwood, T., 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xxii (The Lead and Zinc Ores of the Lake District), 1921.

[2] The occurrence of a lead-vein at Kinniside (mapped, like the haematite-veins in the granophyre, by Mr. Hollingworth) and of copper near Egremont shows that the geographical distribution of the various metals is not simple, but does not negative the general truth of the statement.

[3] As it would appear, following two papers by A. M. Finlayson, 'The Metallogeny of the British Isles,' *Quart. Journ. Geol. Soc.*, vol. lxvi, 1910, pp. 281-98, and 'Ore-Deposition in the Lead and Zinc Veins of Great Britain,' *op. cit.*, pp. 299-328.

[4] 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. viii (Haematites of West Cumberland, Lancashire and the Lake District), ed. 2, 1924, p. 40. This important work will be referred to as 'the memoir.'

[5] 'The Haematite Deposits of West Cumberland,' *Trans. N. Eng. Inst. Min. & Mech. Eng.*, vol. xxviii, 1879, pp. 109-54.

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later occasions[1]. The importance of the veins is emphasized by the more recent developments on them, and it would seem that the following facts are irreconcilable with deposition by descending meteoric waters. A few of the veins have been workable to depths of 600 ft., wholly in Skiddaw Slate, at which level Keltonfell No. 2 Vein is locally 10 ft. wide at a junction with a branch-vein. At less depths thicknesses of 20 ft. of ore were occasionally found in several veins, and in the case of H Vein the ore, even where of this thickness, was mixed with little slate. It is difficult to suppose that any meteoric water that percolates along small faults or mere joint-planes in the soft Kirkstile Slates at the greater depths has much power of replacement. Nevertheless, it would appear, from an examination of many specimens of impure ore taken from the dumps, that the haematite actually replaces the Skiddaw Slate. For, besides lining fissures and filling cavities between fragments of slate and sandstone, it has every appearance of replacing fault-breccia of either kind of rock by a process of spreading through the comminuted interstitial material first and of attacking the larger fragments along innumerable veinlets. Kendall also has concluded,[2] from a study of the workings of his time, that the haematite replaces the country-rock. The replacement appears, however, to have been direct and not to have followed an earlier replacement by dolomite, as suggested by him in one of his later writings.[3]

This evidence outweighs the few facts pertaining to the haematite veins in the Skiddaw Slate that have been, or may be, held to militate against a magmatic origin. Thus, the veins thin away downward, but this is not necessarily an indication of deposition from above, as downward impoverishment is also shown by mineral veins of undoubted magmatic origin in many parts of the world.

The remarkable purity of the average run of ore, to which it owes its value in metallurgy, may also possibly be urged against the magmatic theory. On the other hand, it may be that the abundance of crystals of specular iron of medium or large size is a sufficient indication of a magmatic origin. Such crystals are frequent in pneumatolytic deposits, but appear to be unknown in those of ordinary meteoric waters. Were they formed by such waters, even at considerable depths only, they would be expected in the deeper parts of some gossans in arid countries or in some veins in red beds under conditions precluding pneumatolytic action.

Again, it is unusual for fairly deep-seated iron ores of magmatic origin to consist of haematite to the exclusion of magnetite. The former, apparently without the latter, is, however, abundant in some tin-veins in the Dartmoor granite[4] that are undoubtedly

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[1] See *Mining Mag.*, vol. 32, 1925, p. 137. A magmatic theory has also been advanced by W. McDonald ('West Cumberland Hematite Deposits,' *Iron & Coal Trades Review*, vol. 110, 1925, p. 434).

[2] 'The Haematite Deposits of West Cumberland,' *op. cit.*, pp. 43-4 (of separate).

[3] 'The Iron Ores of Great Britain and Ireland,' 1893, p. 311.

[4] MacAlister, D. A., 'Note on the Association of Cassiterite and Specular Iron in the Lodes of Dartmoor,' *Geol. Mag.*, 1909, pp. 402-9.

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magmatic. It would appear, too, that the argument might be used equally against the meteoric theory.

The hypothesis that both the haematite and the non-ferrous veins in the Skiddaw Slates have been deposited by magmatic waters affords a ready explanation of the similarity of their relations to the country-rock. The fact that the haematite-veins have been deposited not far beyond the limit of deposition of galena may be purely a coincidence, but it is suggestive of a genetic connexion that in Cornwall the lead metallogenetic zone is succeeded by one of iron-ores.[1] It should be added, however, that these ores include not only haematite but also the ferrous compound, chalybite, which is absent from the haematite-veins in the Skiddaw Slates. Also in Cornwall the zones are 'telescoped' and overlap one another, whereas most of the haematite-veins in the Skiddaw Slate have been bottomed and no lead or other non-ferrous ores, except manganese, are present in any, and the workable veins form a group separated from the nearest lead-veins by barren ground.

It has already been suggested by Kendall,[2] from the facts of areal distribution, that the haematite-deposits constitute a zone beyond that of the lead-ores. The later work on the Skiddaw Slates and their contained veins, outlined above, shows that the relationship of haematite to lead-ore is possibly much closer than has hitherto been suspected. In the same paper he concludes that the emission of haematite-depositing solutions in Cumberland and Lancashire has been partly determined by anticlinal axes in the Skiddaw Slates. So far as the area illustrated by Fig. 1 is concerned, the view now suggested differs from Kendall's only in attributing importance (as affording channels for the emission) also to a sandstone group, the Loweswater Flags, in the Skiddaw Slates.

THE HAEMATITE IN THE CARBONIFEROUS LIMESTONE

General Distribution in the Whitehaven District.—To what extent is the magmatic hypothesis negatived or confirmed by facts relating to the haematite ore-bodies in the Carboniferous Limestone?

The map[3] shows the distribution of haematite in the Whitehaven district in both limestone and Skiddaw Slate as well as the interrelations of the two formations. It is seen that south-west of Keltonfell Top the Loweswater Flags are rapidly overstepped by the Carboniferous Limestone, but maintain their strike, in the old platform on which the limestone rests, south-westward as far at least as Frizington. With the exception of that at Lamplugh, close by, ore-bodies are unknown in the limestone for many miles north-east of the region of overlap, but to the south-west they appear in force in a

[1] Davison, E. H., 'The Primary Zones of Cornish Lodes,' *Geol. Mag.*, 1921, pp. 505-12, and *Econ. Geol.*, vol. xxii, 1927, pp. 475-9; H. B. Cronshaw, 'The Structure and Genesis of some Tin Lodes occurring in the Camborne District of West Cornwall,' *Trans. Inst. Min. Met.*, vol. xxx, 1921, pp. 408-49; H. Dewey, 'The Mineral Zones of Cornwall,' *Proc. Geol. Assoc.*, vol. xxxvi, 1925, pp. 107-35.

[2] 'Lateral Distribution of Metallic Minerals,' *Mining Mag.*, vol. xxiii, 1920, pp. 75-80.

[3] The positions of the known ore-bodies in the limestone are taken from Pl. I of Dr. Smith's memoir with slight additions from Kendall's plan of the huge Parkside 'flat' near Frizington ('The Haematite Deposits of West Cumberland,' *op. cit.*, Pl. XXV, fig. 3) and from other mining information (Frizington to Lamplugh).

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distance of about a mile (at Salter Hall) and continue thence without marked interruption to the Florence, Ullcoats and Winscales mines a short distance beyond Egremont, where the limestone is overstepped by the New Red Sandstone. Their appearance close to where the Loweswater Flags pass below the limestone may be a coincidence, but it is clear that if, as suggested, the flag-group has been the path of ascending ferruginous solutions, they would be expected in the overlying limestone where they actually occur.

The flags may well continue south-westward beneath the Carboniferous Limestone as far as Bigrigg, but between that place and Egremont other beds in the Skiddaw Slates, and also Borrowdale rocks, enter the pre-Carboniferous platform. As the ore-bodies in the overlying limestone persist beyond Bigrigg to the termination of the limestone near Egremont, it is evident that those south-east of Bigrigg have not originated directly from solutions arising through the Loweswater Flags. We shall presently see, however, that these ore-bodies differ essentially, in their relations to the geological structure, from those north-east of Bigrigg.

Relations to Geographical Structure.—As regards these relations the most important fact, the close connexion between ore-deposition and faults, is equally explicable on either view of the origin of the ore. It is from the relations of ore-bodies to the base of the limestone (or to older rocks against which the limestone is faulted) that the theory of descending solutions derives its strength. The evidence has been clearly stated and illustrated by Dr. Smith[1], and cannot be gainsaid. In places " the ore lies on the foot-wall of the fault (Skiddaw Slate) and sends out extensions as flats " along the base of the limestone, or it rests on an impermeable shale below a bed of limestone, such as the Fourth Shale (see figs. 11 and 13). If the relations of the ore were similar throughout the field there could be no further question as to the direction of movement of all the solutions. But, as mentioned by Dr. Smith, the ore is found as flats at the base of the limestone only between Egremont and Bigrigg (that is, along that part of its course where the limestone is overlain by the New Red Sandstone directly), and at The Flosh and probably Todholes, along the outcrop of the limestone south of Cleator Moor[2]. At Bigrigg and to the north-east, where impermeable beds (Hensingham Group and higher strata) overlie the limestone, the relations of the ore show a marked change. Not only are the flats at the base lost, but bodies " tend to cluster some distance above the base of the series ". From Bigrigg to Winder, near Salter Hall, replacement of the limestone immediately underlying the Hensingham Group is of frequent occurrence.[3]

[1] *Op. cit.*, p. 38 and, *e.g.*, figs. 5-7 and Pl. V.

[2] Kendall states that " in the north-eastern part of the district iron ore has only been worked in the bottom beds at Parkside " (' The Distribution of Ore in Depth,' *Mining Mag.*, vol. 22, 1920, pp. 282-6, fig. 2 ; see also *Mining Mag.*, vol. 32, 1925, p. 144, fig. 6).

[3] See Figs. 9, 11 and 18 of the memoir. The known ore-bodies in the two parts of the field are contrasted in figs. 2-4 of Kendall's paper ' The Distribution of Ore in Depth.'

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Although, as mentioned in the memoir (from which the quotation above is made), the cover of impermeable beds would cut off descending solutions (and, possibly, by introducing artesian conditions, it may have changed the underground circulation to such an extent that water passed freely along the highest limestone but not along the lowest), the distribution of ore at Bigrigg and to the north-east is at least as readily explicable if it be supposed that along this tract iron solutions have risen along fault-fissures through the limestone and spread here and there beneath one or other of the relatively impermeable shales and sandstones that split up the limestone-mass or overlie it. For in places, as in the case of the 'flat' at the top of a bed of limestone (the Fifth Limestone) at Lamplugh Mine, the ore follows the under surface of a relatively impermeable bed (at Lamplugh a compact sandstone) in the mass of the limestone and is underlain by unaltered limestone. In some localities, *e.g.*, the part of Bigrigg illustrated by fig. 11 of the memoir, one ore-body may underlie one impermeable bed and another may overlie a second. Varying relations of this kind would result in those places where, at different times, ascending magmatic and descending meteoric waters varied in relative influence, and would be expected near the edge of the Hensingham Group cover, as at Bigrigg, or might be found locally beneath the cover itself.

Near Bigrigg, at the basset-edge of the cover, descending meteoric waters would be likely to meet the ascending solutions and, carrying them down through the limestone, could account for the ore-bodies at the base of the limestone to the south-east. But near Winscales, at least, there may well have been a source of ascending solutions independent of any in the Loweswater Flags.

The difference between the north-eastern part of the iron-ore field and the south-eastern end as regards ore-bodies at the base of the limestone is discussed also by Kendall[1], who suggests as the most probable answer that the beds in the north-eastern part have never been bored at the proper place. Be this as it may, the known general distribution of the ore-bodies throughout the limestone may be equally explicable whether the solutions be regarded as everywhere descending or as largely ascending beneath the cover of impermeable rocks and descending where this is absent.

Before leaving this part of the question it should be added that a bed of haematite, probably altered *Spirorbis*-limestone[2], in the Whitehaven Sandstone at Millyeat, near Frizington, seems at first sight to be attributable solely to waters descending from New Red Sandstone, for brockram at the base of the latter crops out at a short distance, whereas the top of the Carboniferous Limestone probably lies more than 1,000 ft. below. If alteration of limestone close below brockram to haematite were at all general, the argument would be unanswerable, but as a fact it is seen from figs. 3-6 and Pl. V of the memoir that limestone in this position, even in the proximity of

[1] 'The Distribution of Ore in Depth,' *op. cit.*
[2] Kendall, J. D., 'The Iron Ores of Great Britain and Ireland,' 1893, pp. 117-9.

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faults, is no more frequently altered than other limestone. The association at Millyeat may therefore be accidental, and a N.N.W. fault, like those that often carry ore in the Carboniferous Limestone, which crosses the brockram, is a possible path of the ferruginous solutions.

Associated Minerals.—The mineral associates of the haematite in the Carboniferous Limestone and the changes they have undergone suggest a magmatic origin rather than deposition by meteoric waters.

As evidence against a magmatic origin may again be urged the remarkable freedom of the haematite from other ores except, in places, those of manganese. Exceptionally a little copper pyrites is associated with haematite at Eskett (near Salter Hall) and galena has been found by Dr. Smith in the limestone at Parkside. The chief gangue minerals, calcite, dolomite, quartz and barytes, afford no criterion. On the other hand fluor, one of the most characteristic deposits of acid magmatic solutions, is present, though in its rarity it contrasts with that in magmatic veins of many places, such as Alston Moor and Derbyshire. But it is less rare than in the lead and zinc veins in the Skiddaw Slate[1], for it has been found at several places and at Florence Pit and Ullcoats is occasionally abundant. Its discovery at these two mines is due to Dr. L. J. Spencer, to whom I am indebted for allowing me to examine his material and publish the following details.

The crystals are generally colourless or, in a few cases, with a red central or outer zone. They are among the latest minerals lining the cavities ('loughs'), the sequence of these last deposits being :— kidney ore and specular iron, quartz, fluor,—at this stage in places interruption by fracturing,—barytes, dolomite, and finally marcasite (occasional), or, after the quartz and fluor, no later mineral or only a light dusting of small crystals of specular iron.

Fluor has also been found at Bigrigg (several mines[2], at Langhorn quarry[3] in the top limestone, and not uncommonly at Fletcher Pit[4]), Cleator Moor[5], old Parkside Mine (not uncommon)[3], and at Kelton quarry in the top limestone. Outside the Whitehaven iron-ore field it occurs lining a joint[6] in Skiddaw Slate half a mile north-east of the Kinniside lead-vein, and has been found in the haematite-mines to the south at Hodbarrow[7] and, replaced by haematite, in Furness.[8]

Although, in general, the powers of replacement of the ferruginous solutions that have deposited the ore-bodies in the Carboniferous Limestone have been feeble, in places they have been considerable

[1] Eastwood, T., *op. cit.*, p. 3.
[2] Information from Mr. J. D. Kendall and Mr. Chas. Edmonds.
[3] Information from Mr. Edmonds.
[4] Kendall, J. D., 'The Iron Ores of Great Britain and Ireland,' 1893, p. 117.
[5] Greg, R. P., and W. G. Lettsom ('Manual of the Mineralogy of Great Britain and Ireland,' 1858, p. 23) and information from Mr. Edmonds (Crowgarth Mine). I have to thank Dr. Spencer for the reference.
[6] Information from Mr. S. E. Hollingworth.
[7] Information from Mr. T. C. F. Hall.
[8] Collections in the Museum of Practical Geology and the Natural History Museum.

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and unusual in character. Under normal conditions of weathering fluor and barytes are stable and practically insoluble. Yet, during the period of deposition of the haematite, crystals of both these minerals were replaced, molecule by molecule, by haematite[1] either directly or, in some cases of fluor described by Miers[2], following a temporary replacement by quartz. And from dump-material it is clear that fairly frequently a growth of haematite has enclosed an earlier deposit of barytes which, later, has been completely removed, in some cases at least within the period of haematite-deposition, as is evidenced by crusts of specular iron in the cavities left by the barytes. That the solution of the barytes has not been the work of meteoric waters through the ages is suggested by the facts that it has seldom, if ever, been partial, and, especially, that it is not unusual for dolomite- or calcite-crystals enclosing the barytes to be left untouched by the solvent.

CONCLUSIONS

1. The veins of haematite, and most of those of lead, zinc and copper ores, in the Skiddaw Slate west of the Derwent valley have been deposited near the junction of the Loweswater Flags (or a similar sandstone-group) with underlying slates, and the main channels for the passage of the metallic solutions have been fault-fissures in the sandstones.
2. Apart possibly from the purity of the ore the facts relating to the haematite-veins suggest deposition by magmatic, not meteoric, waters.
3. These veins may constitute an iron metallogenetic zone, outside one formed by the lead-veins.
4. Ore-bodies of haematite appear in the Carboniferous Limestone of the Whitehaven district where it oversteps the Loweswater Flags.
5. The relations of these ore-bodies to geological structure are consistent with deposition either by ascending magmatic waters where the limestone has an impermeable cover and by descending mixed waters elsewhere, or wholly by descending meteoric waters.
6. The abundance of specular iron, the association of haematite with fluor, rare on the whole but not uncommon in a few places, and the locally intense and abnormal chemical activity of the mineralizing solutions suggest a magmatic, not a sedimentary, origin for the ore-bodies in the Carboniferous Limestone.
7. The general body of evidence relating to the Cumberland haematites therefore, favours the magmatic theory.
8. The association of haematite with red beds in this district would appear to be accidental, not genetic.

The theory of the deposition of haematite by waters from the New Red Sandstone owes its general acceptance partly to the the co-occurrence of haematite with such rocks not only in Cumberland and Furness, but also in North and South Wales.[3] The evidence in each district should be re-examined on its merits. For instance, the replacement of Pennant Sandstone by haematite in the Forest of Dean[4] might, as a result, not be so anomalous as appears at present.

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[1] Rudler, F. W., 'A Handbook to a Collection of the Minerals in the British Isles,' (*Mem. Geol. Surv.*), 1905, p. 147.
[2] 'Some British Pseudomorphs,' *Min. Mag.*, vol. xi, 1897, p. 269.
[3] See, e.g., Smith, B., *op. cit.*, p. 40.
[4] Sibly, T. F., 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. x (the Haematites of the Forest of Dean and South Wales), ed. 2, 1927, p. 1.

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(2).—By Bernard Smith, M.A., Sc.D.

In attributing the origin of the haematite in West Cumberland to a magmatic source Mr. Dixon raises once more the question whether the iron-bearing solutions which effected metasomatic alteration of the rocks descended from above or ascended from below.

Mr. J. D. Kendall, who spent many years in studying the haematite deposits of West Cumberland and Furness, was a protagonist of the magmatic theory. To him we are indebted for convincing arguments in favour of the metasomatic alteration of the Carboniferous Limestone to haematite—a conclusion with which both Mr. Dixon and the writer[1] are in agreement. Mr. Kendall, however, stated that the alteration took place at a date preceding the deposition of the 'Permian' breccia which forms the base of the New Red Series. The writer showed that the date was much later, namely after the accumulation and consolidation of most, if not all, of the Triassic rocks[2]; and it may even have been Tertiary.[3]

Furthermore, the latter argued that the ore in the Carboniferous Limestone, at least, must have been formed by solutions descending from above[4]—without prejudice as to their composition or original derivation. Mr. Dixon accepts this fact of descent for part of the area only, maintaining that the waters were magmatic in origin and that many of the deposits are due to rise of solutions from below and direct attack upon the country rock, whether slate or limestone.

In the search for light upon the origin of the ore and the source of the mineralising solutions no avenue should be left unexplored, yet Mr. Dixon's theory challenges comment, for many of the points raised seem to be inconclusive or may be satisfied by alternative arguments, and some of the conclusions possess a wide implication.

The chief weakness of his case is that no satisfactory evidence is advanced in proof of the contention that the haematite-manganese veins and the other metallic veins (lead, zinc and copper) of the Lake District are of the same approximate date, or have even been derived from the same magmatic source. That both types occur at or near the junction of grits and shales is no argument for a common date, as earth movements likely to rupture the rocks at such points have occurred at various times in Lake District history. Moreover, some of the veins appear to occur outside such locations (Fig. 1, p. 24), and the influence exerted by the Loweswater Flags, as channels for movements of waters, must be extended to the Ennerdale Granophyre and the Borrowdale Volcanics also.

Except for the occurrence of the haematite in vein-like form, there is little resemblance between such 'veins' in the Skiddaw Slates and veins of recognized magmatic origin in the south-west of England. The one group is largely metasomatic, the other fills fissures.

[1] Smith, Bernard, 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. viii (Iron Ores:—Haematites of West Cumberland, Lancashire and the Lake District), ed. 2, 1924, p. 37.
[2] *Op. cit.*, p. 40.
[3] *Op. cit.*, footnote, p. 40.
[4] *Op. cit.*, pp. 38-9.

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No haematite, on the one hand, has been found in the lead, zinc and copper veins of the Lower Palaeozoic rocks of the Lake District. On the other hand, barytes, fluorspar, copper, lead or zinc are wanting in the haematite veins in the Skiddaw Slates, where Mr. Dixon claims that the waters ascended: even in the absence of the non-ferrous metals one might have expected the presence of either barytes or fluorspar, especially as they occur associated with haematite in the Carboniferous Limestone not far away and are appealed to as evidence for the magmatic origin of the ore. No evidence, however, has been adduced to prove that these two minerals, which occur in the limestone, both in association with haematite and beyond its limits, did not precede by a long interval the formation of haematite. The writer is convinced that the copper vein at Anty Cross Mine, Furness,[1] was in existence before it was invaded by the iron-bearing solutions.

Finally, if the non-ferrous mineral veins of the Lake District were formed in some late- or post-Triassic period, one would expect to find occurrences of these minerals in recognisable veins in the circuit of Triassic rocks surrounding the district.

In considering the general distribution of the ore the absence of workable veins of haematite in the Lower Palaeozoic rocks contiguous to the large deposits of ore in the limestone near Egremont and Millom, and in Low Furness—all regions in which there is evidence of downward percolation—militates strongly against the theory of direct ascent from below, or even direct ascent and subsequent descent at the places concerned. On the other hand—in favour of the downward percolation theory[1]—haematite seems to be most strongly represented in those areas fringing the pre-Permian hills where the New Red deposits can be shown to have been stepping across the Carboniferous rocks, and where they occurred either upon, or fairly close above, the Limestone itself. North of Lamplugh it is evident that a thick cover of the Hensingham Group, Millstone Grit and Coal Measures supervened between the Limestone and the New Red rocks, and here we find little or no ore; but farther round the north side of the Lake District, east of Wigton, ore appears again in the Carboniferous rocks underlying the New Red; but dies out in depth.

It must be remembered that a drainage system was operative in the Carboniferous Limestone in early Permian times, and its effects may have had considerable influence upon the anomalous positions, high or low in a bed of limestone, of certain ore-bodies formed later on. As in the Forest of Dean, also, certain beds would be more susceptible to alteration than others.

The mechanical action of "ascending magmatic and descending meteoric waters varying in relative influence" is rather difficult to understand, and it would be a strange coincidence if the solutions

[1] *Op. cit.*, p. 178.
[2] *Op. cit.*, pp. 38-43, 55, 60, 61.

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only ascended where there was a cover of impermeable rocks and descended where that cover was absent. In this connexion it should be noted that the New Red cover is considered by Mr. Dixon to be permeable. Actually the breccia with its shaly layers and the shales at the base of the St. Bees Sandstone, where unfaulted, would have acted as a fairly efficient impermeable cover; whilst the Hensingham Group and possibly Coal Measures, if faulted, might have allowed the passage of waters either way—witness Mr. Dixon's suggested explanation of the occurrence of the Millyeat ore.

This suggested upward and downward movement—an upward movement of magmatic waters highly charged with minerals, and a downward movement of the same diluted and cooled by meteoric waters—should have given rise, one would think, to some differences in their relative effects upon the limestone; yet as far as can be judged, the haematite and its associated minerals are the same in both of the type areas. Fluorspar occurs sparingly in each, yet in the accepted area of downward percolation, south of Bigrigg, the fluorine-bearing solutions would have been so diluted that separation out in loughs in recognisable form would hardly have been possible. Had the crystals been formed, however, by solution of fluorspar deposited at an earlier date and subsequent reformation their occurrence in fair quantity is understandable.

The iron-bearing waters, whatever their direction of attack, were obviously fairly potent at times, although we know little of their actual composition; yet they need not necessarily, have been magmatic. Waters in the Lower Tertiary of Knockmill in Kent[1], which certainly are not magmatic, are capable of dissolving the colloidal silica from chalk flints. In the Sandgate Beds of the Lower Greensand near Godalming[2], spiculiferous cherts are being replaced to-day by hydrous oxides of iron, including goethite. Again, barytes is being dissolved and pseudomorphed by chemical changes now taking place in the veins of the Leadhills and Wanlockhead district[3]. It is therefore possible that fluorspar formed in the limestone at a date previous to haematitisation may have been replaced by solutions or reactions which were non-magmatic in origin. Whatever their source, however, the solutions could not be described as ordinary meteoric waters.

If we consider the matter in its wider implications, despite the suggestion that the evidence in North and South Wales and the Forest of Dean should be re-examined on its merits, one cannot but recognise that if Mr. Dixon's theory is correct these other occurrences of hydrated haematites must be similarly explicable, and one would then have an iron metallogenetic province of late-

[1] Information from Mr. H. Dewey.
[2] Information from Mr. F. H. Edmunds.
[3] 'Special Reports on the Mineral Resources of Great Britain' (*Mem. Geol. Surv.*), vol. xvii (The Lead, Zinc, Copper and Nickel Ores of Scotland), 1921, pp. 20-21.

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or post-Triassic age extending from the English Channel[1] into South Scotland. In practically all the areas where haematite occurs Triassic rocks are either directly overhead or in the near vicinity.

The above criticisms, which do not cover the whole ground, are advanced in the hope that two partially opposed points of view may lead to further light. As the matter stands the writer considers that a direct attack of solutions on the Carboniferous Limestone from below is not yet proved; and whilst, conceivably, there may have been some such action in the Skiddaw Slates, this also, in so far as it rests very largely upon the supposed relationship of the ferrous to the non-ferrous veins of the Lake District, is open to doubt.

[1] Haematite occurs in Mid-Devonian Limestones (again close beneath Triassic cover and under conditions resembling those of the Furness 'sops') at Sharkham Point, Brixham Devon, far removed from the usual metallic lodes.

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IV.—THE STRATIGRAPHICAL POSITION OF THE MANCHESTER COAL MEASURES

By LAURANCE H. TONKS, M.Sc.

Text-figures 1 and 2.

Among the problems that have arisen from time to time in the Lancashire coalfield none perhaps has led to such general confusion as the question of the true position of the measures exposed and proved at Manchester. Stratigraphical considerations and comparisons of pit-shaft records led the writer to the same correlation by grouping of coals that Professor G. Hickling has given in his later publications.[1] The numerous approximations involved in these methods, however, make such correlations articles of belief rather than of knowledge, and in this instance the inference to be drawn regarding the stratigraphical succession is of such fundamental importance that definite proof is desirable. Through the courtesy of the owners of the Bradford and Moston collieries, who permitted a detailed examination of their tunnel sections, such proof has been attained. It was realised that if the correlation was correct the marine band which occurs 200 yards above the Sod (Pottery) Mine at Dukinfield [2] would be found in the tunnel sections available. Confirmation was also to be expected from a comparison of the faunas of the musselbands in such portions of the two sections as afforded an overlap of strata. These anticipations were more than realised.

The measures from the Parker [3] to the Deep Mine at Bradford were examined in the return airway, which runs from the Deep Mine levels to the bottom of the Parker shaft. At Moston, the two main roads which are called the Platt and Hardman tunnels, have given a section from the Platt Mine to a distance of nearly 500 ft. above the Colonel. Another tunnel extends this section downwards from the Platt to the Black Mine. The beds exposed in the tunnels were examined, their lithological characters noted, and the fossiliferous horizons located. These fossiliferous bands were investigated underground only in so far as was necessary for the determination of their character and thickness. The colliery management then arranged for the getting of a tub (or tubs) of material from each band, which, after being numbered, were sent to the surface. The actual collecting of fossils was done at the pit-head, and it is difficult to see how it could have been done efficiently underground, so that in this and other ways, the free and friendly assistance of Mr. Fisher, manager at Bradford, and Mr. Richford,

[1] Explanatory Notes to the Contour Map of the Trencherbone Seam, 1924. 'Sections of Strata of the Coal Measures of Lancashire,' 1927.

[2] Lloyd, W., 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 62.

[3] For the general horizon of these measures see Figs. 1 & 2.

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manager at Moston, removed many difficulties. To them, and to the companies concerned, very sincere thanks are offered.

The vertical sections constructed from the observations made in the tunnels are given in Fig. 1. It will be seen that a detailed examination of the sequence from the Black to the Parker Mines has been made, and the fossils from some twenty *Carbonicola* bands, many of which are recorded for the first time, have been collected. At this early stage it is not possible to use specific names or descriptions with safety. Certain broad statements can, however, be made.[1] Specimens of *Anthracomya* are rare, those of *Naiadites* more common, but both these genera are subordinate in most bands to *Carbonicola*, which occurs in profusion. *Anthracomya* and *Naiadites* occur most frequently in black shale and mudstone: *Carbonicola* in grey mudstone. Complete and uncrushed specimens are of comparatively frequent occurrence. Bands of ironstone and limestone crowded with *Carbonicola* are common. These '*Carbonicola* limestones' are exasperating and unsatisfactory, for, of all the numberless fossils visible in the rock, it is but rarely that one good specimen can be obtained. Some of the bands show marked lithological characters, such as cone-in-cone ironstones, felted mudstones and the like, which may prove to be additional aids in correlation. Distinctive palaeontological character has already been observed in certain bands. The Stubbs Mine horizon (MC 9), for example, is characterised by a rich fauna with certain definite and restricted forms. It is thought that the group of coals with plant-bearing roofs which are followed by the bands MC 1 and 2 may be recognisable elsewhere. Again, the Foxholes-Colonel Mine belt is noteworthy. The grey mudstones overlying the Foxholes and Colonel Mines are crowded with beautifully preserved plant remains. The Roger roof is barren, and below the Roger occur two thin but well defined beds of *Carbonicola* limestone.

On the other hand, the band above the Platt Mine (MC 0) was disappointing in the tunnel section at Moston. The Platt Mine has been correlated with the Blenfire, but it seems more likely that at Moston the Blenfire is washed out by the massive Blenfire Rock, as it is known to be in some other localities, and that the Platt is on or about the position of the Great Mine of Oldham. On Oldham Edge a thick *Carbonicola* bed occurs between the Great Mine and the Blenfire. This bed is remarkable for the abundance and variety of the forms that occur in it. It was expected that the presence and position of this band in the tunnel would afford incontrovertible evidence of the true position of the Platt Mine, but although species of *Carbonicola* were found in hard black shale of some thickness between the Platt Mine and the base of the Blenfire Rock, they were scarce and unvaried in form in comparison with the band of Oldham Edge, even allowing for the difficulty of collecting from this type of shale in its unweathered condition.

[1] The specimens collected have been worked through by Mr. W. B. Wright, who has provided the material for these brief notes on the palaeontological character of the bands.

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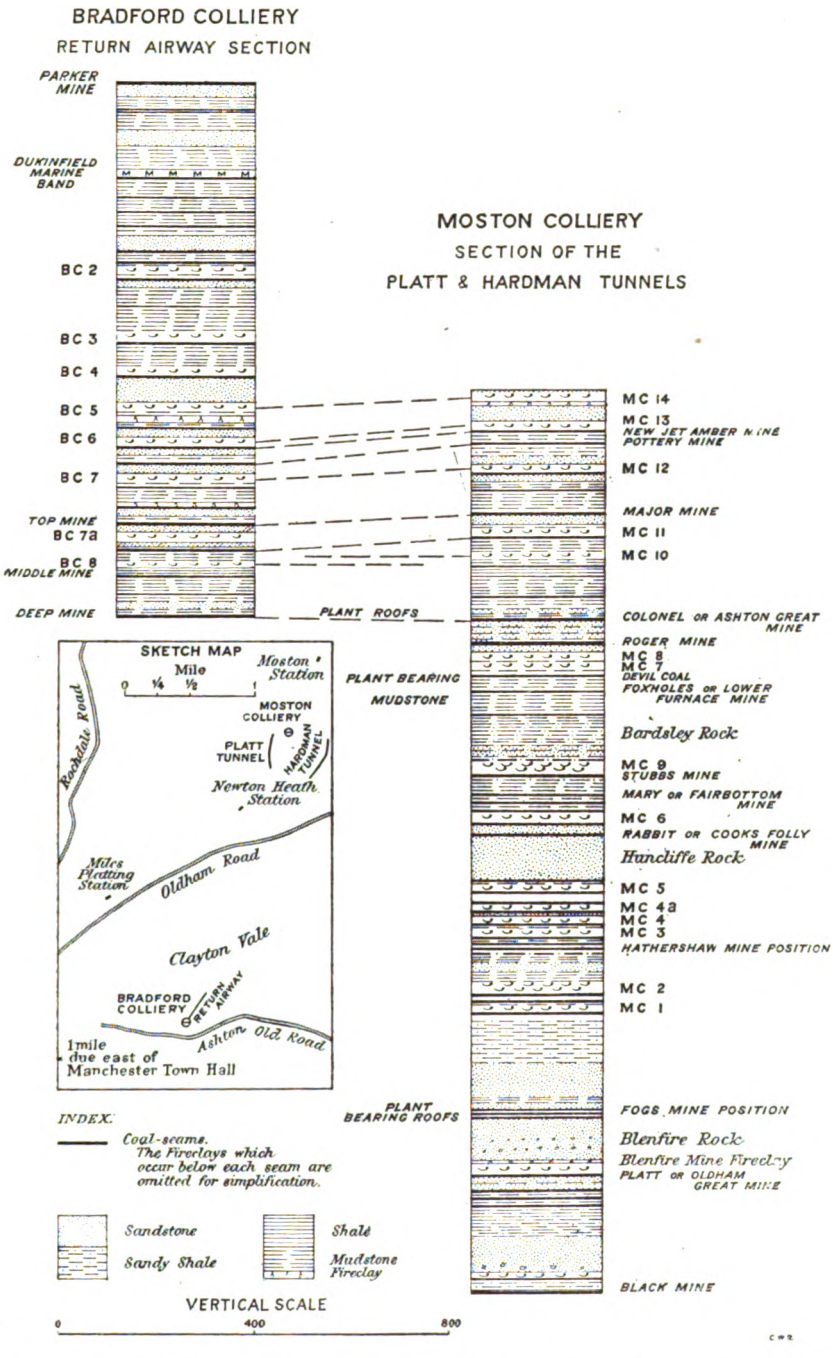

FIG. 1.—*Vertical Sections of the Manchester Coal Measures at Moston and Bradford Collieries.*

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It can be seen in Fig. 1 that there is an overlap between the Bradford and Moston sections of 480 ft. The lithological character of the measures and the distances apart of the coal seams compare sufficiently well to give an approximate correlation of the Bradford Deep Mine with the Moston Colonel, but another check is available in the *Carbonicola* bands which occur in this " overlap."

The bands marked M C 12 and B C 7 both occur over a coal 1 ft. 6 in. thick, and lie at the same vertical distance above the Major Mine in the one case, and the Bradford Top Mine in the other. Numerous forms occur, including varieties restricted to this horizon, which are common to both localities. This is so marked a feature that there can be no doubt of the identity of these two bands. No differences have been observed in the fauna of M C 13 and B C 6 and there is no reason to doubt that they are the same bed. M C 14 is poorer in fauna than B C 5, but there is no distinctive character in either.

The other bands of the " overlap " are extremely interesting. B C 7a and M C 11 may not be on precisely the same horizon, but there is no evidence to show that this is the case. They are totally distinct in fauna and this difference is accompanied by a change in lithological character. Small species of *Anthracomya* and *Carbonicola* occur in B C 7a in grey mudstone, with a thin calcareous band at the base. M C 11 consists of about 3 inches of *Carbonicola* limestone and 1 ft. of black shale in which species of *Anthracomya* are found. These bands are not only different as between themselves, but they do not resemble other bands above or below. It seems most probable that the difference between the two is due to a lateral change in lithological and palaeontological character between Moston and Bradford.

There are differences in the faunas of the bands B C 8 and M C 10 but the two bands are on different stratigraphical horizons. B C 8 occurs in cannelly shale about 5 ft. above the Bradford Middle Mine. The same shale occurs above the equivalent coal at Moston, but did not yield fossils. The scantiness of the fossils at Bradford had been so marked that little surprise was occasioned by their absence at Moston. M C 10 is a *Carbonicola* limestone 45 ft. above the coal with the cannel shale roof, and at Bradford no fossiliferous band was found in this position. The two bands are linked, however, by the presence in both, of specimens of a small ovoid *Carbonicola* with wrinkled periostracum ; a form which has not been observed at any other horizon.

Of the six *Carbonicola* bands which occur in the 400 ft. of beds above the Colonel Mine, the M C 12—B C 7 band is by far the most important. This statement is not made merely on account of the fact that the faunas at Bradford and Moston are the same, but because elements of its fauna are sufficiently distinct from those of the bands above and below to render the observed faunal identity a thing of real value. This being the case, the correlation of the Bradford Top Mine with the Major Mine of Moston, and the correla-

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tion of the coal next above B C 7 with the Pottery Mine of Moston is confirmed.

The Pottery Mine of Moston and Bower is the Sod Mine of Dukinfield,[1] and 600 ft. above the Sod Mine lies the marine band discovered long ago by Green. The final confirmation of the

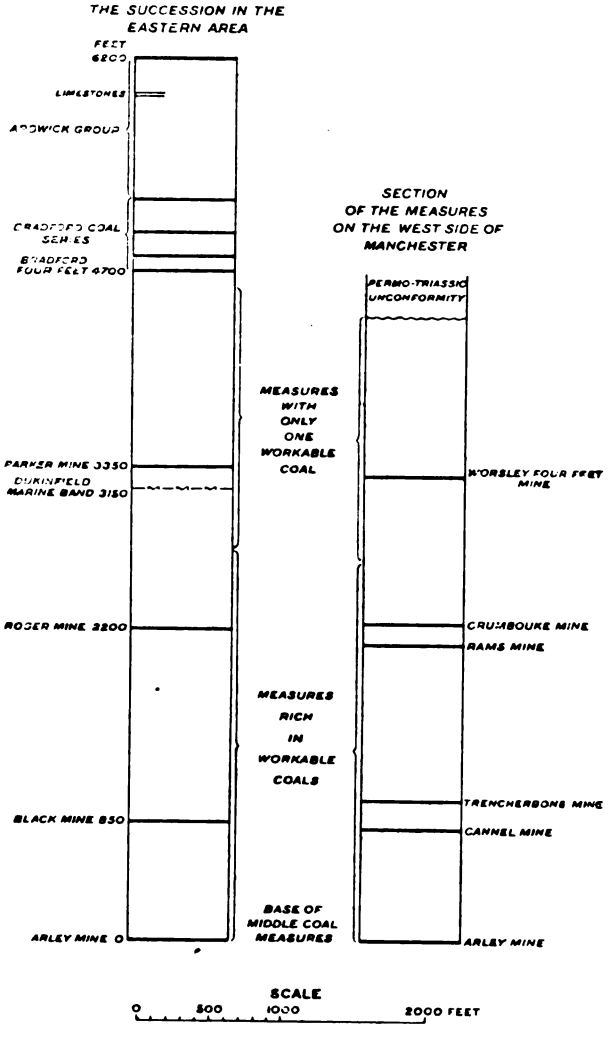

FIG. 2.—*Vertical Sections of Coal Measures east and west of Manchester.*

correlation put forward by Professor Hickling is afforded by the discovery of a marine band 600 ft. above the coal that is correlated with the Pottery Mine in the Bradford section. The band consists of 1 ft. 3 in. of limestone with marine shale above it. The fauna

[1] Lloyd, W., 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 63, fig. 2.

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does not appear to be either rich or well-preserved, and in this respect, as in lithological character, it resembles the band at Dukinfield. Marine fossils have not been found elsewhere in the sections examined.

The fresh limestone of the band is exceedingly hard and over a foot thick, and its character should preclude the possibility of its having been overlooked by shaft sinkers and borers. Yet although these measures were bored through below the Parker shaft, and the Deep shaft passes through them, no record of this limestone occurs in the journals of either boring or shaft sinking. This hard resistant rock is included in the item : " Metal : 8 yds. 2 ft. 2 ins." in the one case, and in : "Grey bind : 65 ft. 10 ins." in the other. In view of the use to which the Abdy and Mansfield Marine Beds have been put in the Yorkshire and Nottinghamshire Coalfields and the lack of any knowledge as to the extensive occurrence of any similar horizons in Lancashire, the omission becomes all the more startling, and, in addition, seems to emphasise the importance of the detailed examination of such tunnel sections as can still be seen.

At the top of the succession in the isolated Manchester (Bradford) Coalfield occur the red beds of the Ardwick Series, the highest Carboniferous strata known in Lancashire, and although the relation of these to the Bradford coals has always been clearly understood, it is only recently, as Professor Hickling points out,[1] that their position with reference to the Oldham succession to the east has been realised. Fig. 2 gives a skeleton section of the complete sequence on the eastern side of the coalfield. For the sake of comparison, and, it may be added, clarity, a section of the measures in the Pendleton area, on the west side of Manchester, is placed alongside. No correlation of any part of these two sections is here attempted or intended, but it is at least clear that the earlier correlation of the Bradford 4-ft. Mine with the Worsley 4-ft. Mine introduced much of the confusion that has arisen.

[1] ' Sections of Strata of the Coal Measures of Lancashire,' 1927, p. 21.

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V.—THE ROCHDALE ROAD SEWER TUNNEL SECTION, MANCHESTER

By LAURANCE H. TONKS, M.Sc.

Text-figures 1 and 2.

The cutting of a large sewer tunnel along Rochdale Road, Manchester, provided a splendid opportunity for the examination of the Permo-Triassic rocks and Coal Measures west of the St. George's Fault, which had previously been seen only in scattered exposures in the Irk valley.[1] The section described in this paper extends along Rochdale Road from a point 30 yds. south of Nelson Street, Newton, to Pickering Street, Harpurhey. Along this portion solid rock was seen continuously, but from Pickering Street northwards to Blackley the tunnel was cut in drift. This was also the case in the southerly continuation of the sewer from Nelson Street to Miller Street and along Great Ancoats Street, except where Bunter Sandstone was proved in places.

A section of that part of the tunnel which is to be described is given in Fig. 2. It is 10 ft. in diameter at the Nelson Street end and 9 ft. at Pickering Street, and lies at depths varying from 100 to 180 ft. below the surface. Shafts were sunk to tunnel level at Ashton Street, Zinc Street, Collyhurst Street, Paget Street, Scropton Street and Central Avenue.

Description of the Section.—The marly red sandstone (Bunter) seen south of Nelson Street calls for little comment. It did not contain pebbles here or south of Central Avenue. An increase in marliness downwards marked its passage into the Manchester Marls below. These red marls were not fully exposed in the sewer, as a fault at Limer Street cut out part of their thickness. This appears to be about 150 ft. in this district, from evidence afforded by surrounding boreholes. 98 ft. of marl was proved in the sewer, so that the throw of the Limer Street fault is about 50 ft. down to the south. Immediately south of the fault the beds dip at 7° south-west, but to the north their dip is 14° in the same direction.

In this part of the sewer no fossiliferous limestone bands were present in the marls. This affords an illustration of the varying character of these thin limestones, for Binney has described[2] fossiliferous limestone bands from the sections formerly exposed in the valley of the Irk at a point only 300 yards north-west of this sewer tunnel section.

The junction of the marls with the underlying Collyhurst Sandstone was a conformable one; and this observation confirms that

[1] One-inch Sheet 85; six-inch map, Lancs. 104 N.E.

[2] 'Sketch of the Geology of Manchester and its vicinity,' *Trans. Manch. Geol. Soc.*, vol. i, 1841, pp. 54-6.

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made long ago by Binney in the Irk valley.[1] The Collyhurst Sandstone presented its usual characters of a soft red medium grained sandstone, with coarser bands of millet seed grains. Such bands were found throughout the rock. The full thickness proved in the sewer was 293 ft., and the base of the rock was uneven and cut across the bedding planes of the Coal Measure shales below.

A vertical thickness of 915 ft. of Coal Measures was proved from Zinc Street northwards to the big fault 250 yds. south of Boardman Street. The character of these measures is shown in the vertical section (Fig. 1) and their position in the horizontal section (Fig. 2). No fossils were seen anywhere in this belt of strata. The red and variegated marls immediately below the Collyhurst Sandstone belong to the Upper Measures (the Ardwick Limestone Series). Their base is taken at the 4-in. coal seam, below which grey and normal type Coal Measures become dominant. The fault north of the Collyhurst Street shaft throws down northwards, i.e. against the dip; and its effect is, therefore, to repeat beds previously seen in the tunnel. If this fault had any considerable throw, the upper Coal Measure marls and the underlying grey shales with coal seams would have been proved again on the north side of the fault, but as these are absent, it seems certain that the throw can only be a few feet. The fault south of the Scropton Street shaft is considered, for reasons stated later, to have a throw of several hundred feet. The downward change in hade of this fault, from 30° to 45°, is of interest.

The north boundary fault of the Bradford coalfield was proved at a point 250 yds. south of Boardman Street, some distance south of the position provisionally assigned to it by Hull. In the horizontal section (Fig. 2) the hade shown is somewhat greater than the true hade, which is about 45°, as the tunnel cuts the line of the fault obliquely. The approach to this fault was marked by a turnover of the measures, accompanied by repetition and crumpling of the beds against the fault plane. On the downthrow side of this fault the Manchester Marls were proved for a short distance, until faulted against the Bunter Sandstone which extended northwards to the shaft at Central Avenue. About 12 yds. north of the shaft the Manchester Marls were again proved. Drift deposits occupied a small hollow, apparently caused by a fault, at this junction of the marls with the Bunter Sandstone, and the absence of any suggestion of a passage from the marl to the sandstone might be due to such a fault. The marls extended about 250 yds. farther north, but at this point the base of the drift descended below tunnel level.

Correlation.—The only sections with which the measures proved in the sewer tunnel can be compared are those on the east side of the St. George's Fault. The nearest point at which the full thickness of the Collyhurst Sandstone is known is at the Hydraulic Power Station borehole, Pott Street, 1,100 yds. to the south, and on the

[1] *Op. cit.*, p. 57.

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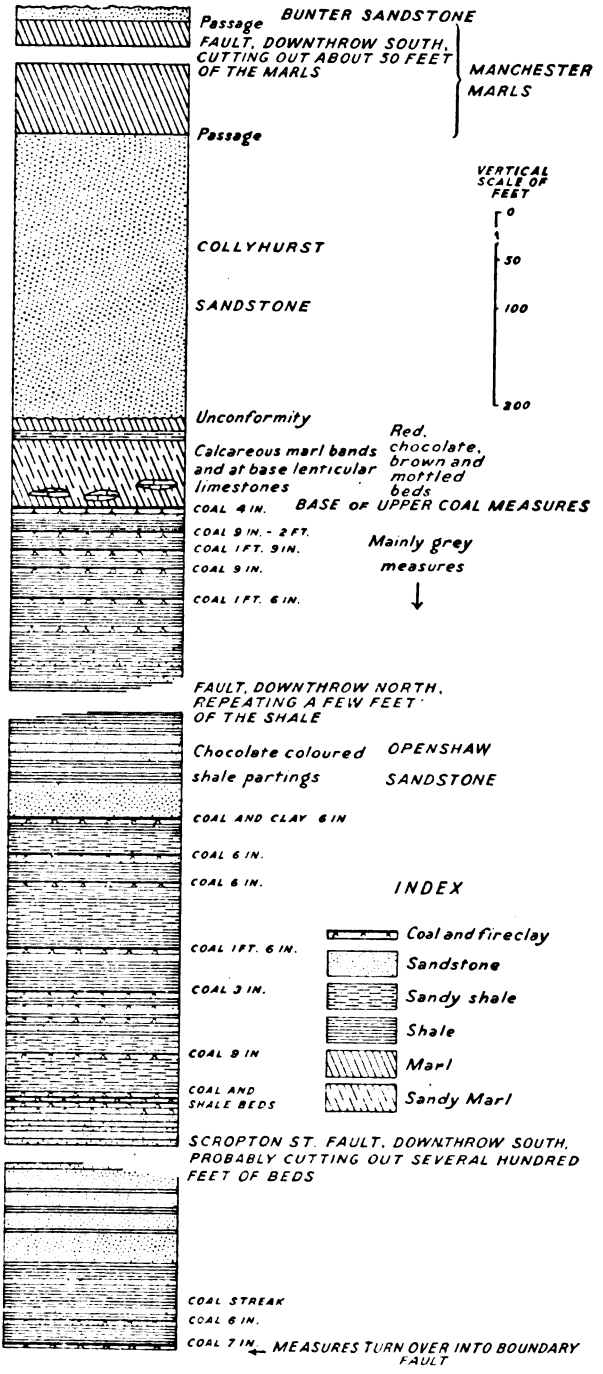

FIG. 1.—*Vertical Section of rocks shown in Rochdale Road Sewer.*

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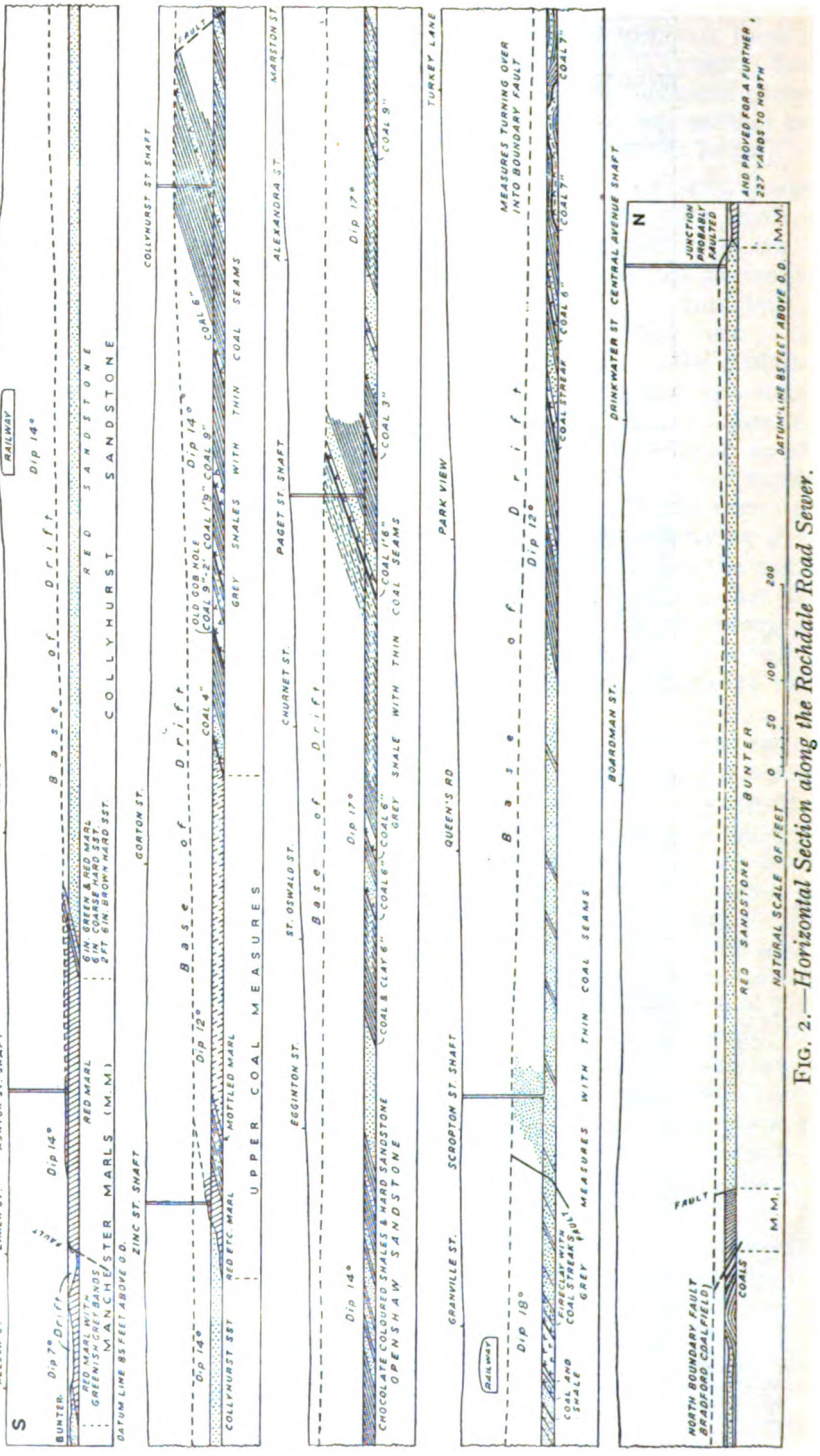

FIG. 2.—*Horizontal Section along the Rochdale Road Sewer.*

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upthrow, or eastern side of the St. George's Fault. The distance separating these points is, of course, less if allowance is made for the post-Triassic movement along this fault. At the tunnel section the Collyhurst Sandstone is 293 ft. thick and at the Pott Street borehole, 136 ft. That this is not simply a normal directional thickening is shown by the fact that 1,100 yds. farther south at Messrs. Deakin's Brewery borehole in Broardie Street, the Collyhurst is 184 ft. thick. It seems impossible to resist the conclusion that there is a causal connexion between the increase in thickness and the positions of the two sections on opposite sides of the St. George's Fault, and that the striking increase in thickness on the downthrow side is due to intra-Collyhurst movement along this fault.

The Pott Street borehole also affords further evidence of the unconformity at the base of the Permo-Triassic rocks. At this borehole the Collyhurst Sandstone is 9 ft. above the Great Mine Limestone, and at the Ardwick Lime Works, one mile away, 300 ft. of marls with limestones occur between this limestone and the base of the Collyhurst.[1] By calculation and projection from the Pott Street borehole it is found that at the sewer tunnel section the base of the Collyhurst is at an horizon about 350 ft. below the Great Mine Limestone. Adding to this the 100 ft. of Coal Measure marls proved in the tunnel, it appears that the base of the red and variegated marls lies at a distance of 450 ft. below the Great Mine Limestone. The characters of the beds below this limestone are not known at Ardwick, but, as Professor Hickling has pointed out[2], these measures have been proved in the High St. Baths borehole, where 600 ft. of red and variegated marls and shales were found to lie below the Great Mine Limestone.

There is very little definite information to work with in making a comparison between the Coal Measures of the tunnel section and the series at Bradford. The uppermost known seam of the Bradford Series is the Openshaw Mine, about 700 ft. below the Great Mine Limestone. This, an estimated vertical distance calculated from the old exposures in the valley of the Medlock,[3] is probably fairly accurate, as the dip and the absence of faulting are proved by the extensive mining operations which have taken place in this area. 400 ft. of measures separate the Openshaw Mine from the Bradford 4-ft. Mine, of which the uppermost 150 ft., above the Charlotte Mine, are unknown. Below the Bradford 4-ft. Mine, 2,430 ft. of Coal Measures have been proved in the Deep Shaft at Bradford Colliery.

Thus, very little is known of the beds between the Great Mine

[1] Dickenson, J., 'The Leading Features of the Lancashire Coalfield,' *Trans. Manch. Geol. Soc.*, vol. 29, 1904-6, p. 244.

[2] Hickling, G., 'The Geology of Manchester as revealed by borings,' *Trans. Inst. Min. Eng.*, vol. liv, 1918, p. 382.

[3] See Binney, E. W., 'Sketch of the Geology of Manchester and its Vicinity,' *Trans. Manch. Geol. Soc.*, vol. i, 1841, pp. 35-66; J. Dickenson, 'On the Coal Strata of Lancashire,' *op. cit.*, vol. 4, 1862-4, pp. 155-175; and the more recent discussion by Hickling in his paper on the Geology of Manchester.

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Limestone and the Charlotte Mine. Dickenson's section[1] at Newton and Ardwick is very generalised, and in the upper part consists of such items as " Coal : 3 ins. ; Shale, etc., with sandstone, called the Openshaw Sandstone : 146 yds." This section serves chiefly to show that two important sandstones, the Holt Town Sandstone, and the Openshaw Sandstone, are found in this belt of strata ; but their precise position is indefinite. Mellor's section of the Ardwick Series,[2] however, gives the position of the Holt Town Sandstone at about 70-80 ft. below the Great Mine Limestone. This limestone and the Holt Town Sandstone, however, disappear westwards below the Permo-Triassic unconformity before the St. George's Fault is reached. Consequently in the sewer tunnel section it is probable that the thick sandstone series occurring about Egginton Street represents the Openshaw Sandstone. From the old map it appears that the Openshaw Mine, 3 ft. thick, lies immediately below this sandstone at Bradford. The absence of any coal of this thickness in the tunnel may perhaps be explained by supposing that it has been cut out by the overlying sandstone. In any case, there does not appear to be any other known rock near the probable stratigraphical horizon of these measures to which this sandstone of the tunnel section can be assigned. Assuming the approximate correctness of this correlation, then a comparison with Dickenson's section and the sections of the Bradford Colliery shafts suggests that the 1 ft. 6 in. coal below may be the Charlotte Mine (Fig. 1), and that the coal and shale beds immediately above the lowest fault may be about the horizon of the Three Quarters Mine. This suggested correlation involves the assumption that the Bradford 4-ft. Mine is cut out by the Scropton Street fault. The roof of this coal is so well characterised[3] that its presence in the tunnel section could not have been overlooked. It must be borne in mind that no great certainty is felt in the correlation set out above, and that it is to be considered simply as a working hypothesis, held for the present until further boring or other explorations lead to a more precise correlation.

In the measures on the north (upthrow) side of the Scropton Street fault a thick and massive sandstone is the only striking feature. As this fault throws down to the south-west, that is, in the same direction as the dip, these beds are older than those to the south. If the throw of this fault is comparatively small this sandstone lies about the horizon of the Bradford 4-ft. Mine or a little below it. The first thick sandstone below the Openshaw Sandstone, however, is a rock 120 ft. in thickness, 820 ft. below the 4-ft. Mine ; and it would seem that this is the only sandstone in the sequence proved at Bradford with which the Scropton Street sandstone can be compared. If this is the correct reading of this part

[1] *Trans. Manch. Geol. Soc.*, vol. 4, 1862-4. Chart.

[2] Dickenson, J., 'The Leading Features of the Lancashire Coalfield,' *Trans. Manch. Geol. Soc.*, vol. 29, 1904-6, p. 244.

[3] Gerrard, J., 'Notes on fossils found above the Bradford Four Feet Coal at Bradford Colliery, Manchester,' *Trans. Manch. Geol. Soc.*, vol. 28, 1902-4, pp. 555-562.

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of the section, then the Scropton Street fault is a branch of the St. George's Fault, taking on the greater part of the throw of the latter.

The correlation of part of the measures proved in the tunnel with the measures above the Bradford 4-ft. Mine involves certain difficulties. By calculation it was found that the base of the red upper Coal Measures in the sewer tunnel section lies at a distance of 450 ft. below the Great Mine Limestone. Adding to this the 640 ft. of 'normal' Coal Measures, which by the suggested correlation are considered to be above the Bradford 4-ft. Mine, the figure of 1,090 ft. is arrived at for the distance between the Great Mine Limestone and the Bradford 4-ft. This agrees well with the thickness between these beds at Newton and Ardwick, which is 1,100 ft. The High Street Baths borehole, however, shows a thickness of 600 ft. of red and variegated measures below the Great Mine Limestone. Although situated 2½ miles south of the sewer section, this evidence cannot be ignored, as it is the only place in which any thickness of measures below the Great Mine Limestone has been proved. If it be assumed that the calculated thickness of the red measures at the sewer tunnel is correct, and that there is approximately the same distance between the Great Mine Limestone and the Bradford 4-ft. in the different localities, then the difference in thickness of the red measures may be explained by postulating lateral change in the character of the strata. That is, that beds which are normal Coal Measures at the sewer section change into red measures southwards. On the other hand, some unforeseen error of calculation or projection may nullify the estimated thickness of red beds at the sewer tunnel; and if this thickness is here also about 600 ft., not 450 ft., then there is, on the downthrow side of the St. George's Fault, about 1,250 ft. of beds between the Great Mine Limestone and the Bradford 4-ft. Mine, compared with 1,100 ft. on the upthrow side of the fault. Such a state of affairs would be explained by postulating movement along this fault during the deposition of the upper part of the Coal Measures. The downthrow of the fault in the Coal Measures is about 900 ft. and this is much greater than the total of the movements which took place:

(*a*) possibly during the deposition of the upper part of the Coal Measures;
(*b*) during the deposition of the Collyhurst Sandstone;
(*c*) after the deposition of the Bunter;

so that there must also have been another movement, probably the main one, along this fault line after the deposition of the Coal Measures, and before the Collyhurst Sandstone was laid down.

Mining operations in the Parker Mine, 1,350 ft. below the Bradford 4-ft., have been carried some distance beyond the position in which this fault should have been proved in the deeper seam if its apparent hade in the upper measures continued downwards. At depth, therefore, its hade must increase fairly rapidly, and in this connexion it is perhaps of interest to note the flattening of the plane of the Scropton Street fault, which, for other reasons, has been

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taken to be a branch, taking most of the throw of the St. George's Fault.

In conclusion, the writer wishes to express his thanks to the Manchester City Engineer, Mr. J. B. L. Meek, for permission to examine the section; and also his indebtedness to the Resident and Assistant Engineers, Messrs. Bullough, Kent, Uttley and Ashworth, for the ready way in which they facilitated the work of visiting the tunnel.

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VI.—WHITTINGTON RAILWAY CUTTING

By G. V. Wilson, B.Sc.,

Text-figure 1.

An excellent section of the measures between the Yard and the Deep Hard Coals has recently been exposed in the process of widening the cutting on the London Midland and Scottish Railway (main line) between New Whittington and Barrow Hill stations, about three miles north east of Chesterfield. In the course of the investigation we have been greatly helped by Mr. R. T. McCallum of the railway engineering staff. He has presented us with a section from which the diagram (Fig. 1) is reduced, and the lists of fossils are mainly compiled from specimens collected by Mr. W. C. Whitmore of the L.M.S. The section was also visited by Mr. S. G. Clift of University College, Nottingham, who has furnished us with information about certain of the beds of fresh water mollusca. The plants have been named by Dr. R. Crookall of the Geological Survey, and the mollusca by Dr. A. E. Trueman of University College, Swansea.

The cutting is situated on the eastern side of the Brimington anticline about 300 yds. north east of New Whittington Station in One-inch Sheet (N.S.) 100; Six-inch Sheet, Derby 18 S.W. The beds dip E.N.E. at an angle of about 24 degrees, and the strike crosses the rails at an angle of about 75 degrees.

The section starts about 150 ft. above the Silkstone Coal which outcrops 100 yds. east of Whittington Station. The lowest beds consist of shaly sandstones and are considered to represent the Silkstone Rock. Six well developed coal seams were exposed. Their names are given below, and compared with those given on a tracing taken from a section prepared in 1844, soon after the railway was made.

New Cutting	**Old Cutting**
Deep Hard	Potters
Piper	Piper
Hospital or 2nd Piper	(Not named)
Tupton or Low Main	(Not named)
Tupton Three Quarter	Tupton or Dogtooth
Yard	Tupton Three Quarter

At Fouleyoaks Colliery near Old Whittington the Hospital is described as the Dogtooth, The Tupton as the Cockle Shell and the Tupton Three Quarter as the Tupton. From the above it will be seen that much confusion exists in the naming of the seams in this part of the country. The work of Dr. Trueman and Mr. Clift on the fresh water mollusca of the Middle Coal Measures of Nottinghamshire is beginning to throw light on the correlation of the various seams. For instance it has been found that the shales above the

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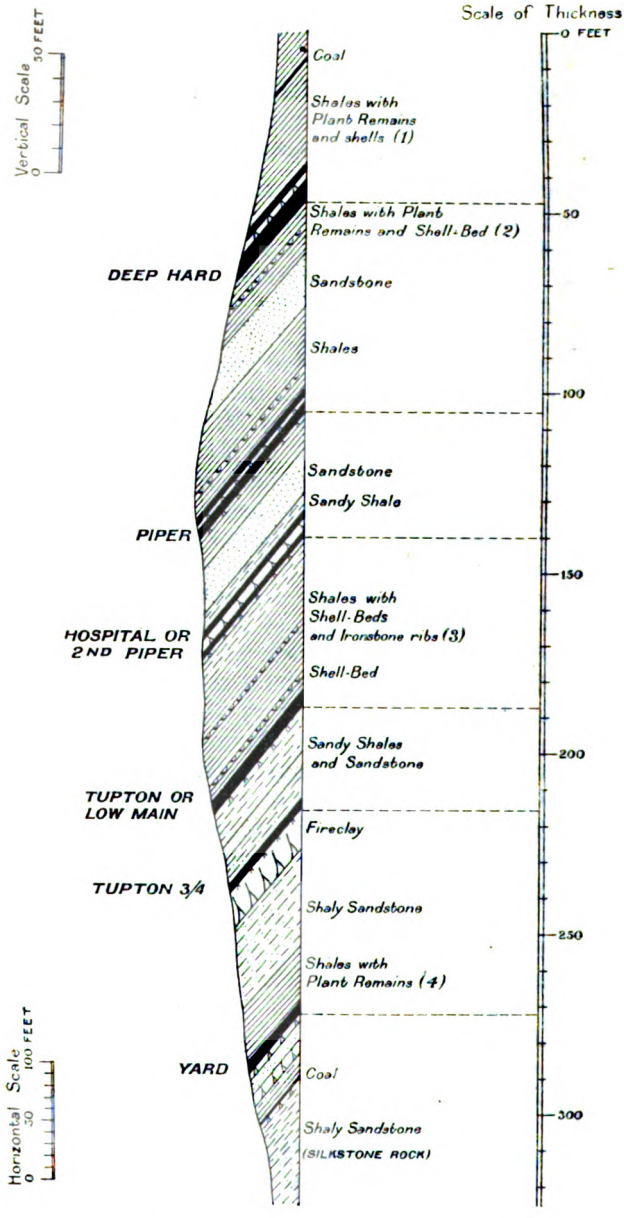

FIG. 1.—*Horizontal Section of the Whittington Railway Cutting.*

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Tupton or Low Main seam are characterised by the presence of certain facies of the shells *Carbonicola rhomboidalis* and *C. acuta.* These forms are well developed in the shell-beds which occur in the shales that are shown in the section (Fig. 1), as occurring between the Tupton and 2nd Piper Coals.

LIST OF FOSSILS.

Animals.

Fresh water mollusca.

Carbonicola *cf.* acuta (*J. Sow.*) (1) (3).
,, *cf.* communis *Davies and Trueman* (3).
,, *cf.* ovalis (*Martin*) (3).
,, *cf.* robusta (*J. de C. Sow.*) (3).
,, *cf.* rhomboidalis *Hind* (2) (3).
Naiadites *cf.* triangularis (*J. de C. Sow.*) (3).

Plants.

Cordaitales.

Cordaites principalis (*Germar*) (1) (4).

Equisetales.

Asterophyllites charaeformis (*Sternb.*) (4).
Calamites carinatus *Sternb.* (4).
,, cisti *Brongt.* (4).
,, undulatus *Sternb.* (4).
,, sp. (4).
Pinnularia capillacea (*L. & H.*) (1).

Filicales.

Asterotheca miltoni (*Artis*) (1).
Dactylotheca plumosa (*Artis*) (1).
Dolerophyllum sp. (2).
Neuropteris heterophylla *Brongt.* (1).
,, tenuifolia *Schloth.* (1).
Sphenopteris sp. (1).

Lycopodiales.

Lepidodendron ophiurus *Brongt.* (2) (4)
,, sp. (2).
Sigillariophyllum bicarinatum (*L. & H.*) (4).
Stigmaria ficoides (*Sternb.*) (4).

Sphenophyllales.

Sphenophyllum sp. (1) (2).

The figures refer to beds shown on the section (Fig. 1).

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VII.—THE DISTRIBUTION OF SANDSTONES IN THE MEASURES ABOVE THE BARNSLEY OR TOP HARD COAL IN THE NORTHERN PART OF THE CONCEALED COALFIELD OF YORKSHIRE AND NOTTINGHAMSHIRE

By G. V. Wilson, B.Sc.

Text-figures 1 and 2.

The chief difficulty encountered in the process of shaft-sinking in the concealed part of the Yorkshire and Nottinghamshire coalfield is the large volume of water yielded by the soft sandstones of the Trias. The sandstones of the Coal Measures usually are dry, but occasionally this is not the case. In certain instances as much as 1,200 gallons of water per minute have been encountered, and sinking operations have been held up until suitable pumps could be installed.

Although it is not possible to determine whether a sandstone at any locality is likely to yield a lot of water, it is considered that it would be of use, if the number of sandstones that might be met with in a sinking could be ascertained beforehand. With this purpose in view, a number of small maps have been prepared, on which an attempt is made to show the possible lateral distribution of certain sandstone horizons of the Middle Coal Measures.

In an area such as the one under consideration, in which there are no surface exposures of Coal Measures, and where our knowledge of the geological succession is limited to that supplied by shaft-sinkings and borings, it is very possible that the correlation of the various sandstones from section to section is incorrect. It has, however, been found convenient to divide the sandstone horizons into three groups :—

(1) Sandstones above the top Marine Bed (where identified), otherwise above the Shafton Coal.
(2) Sandstones lying between the Top Marine Bed or the Shafton Coal and the Mansfield Marine Bed.
(3) Sandstones between the Mansfield Marine Bed and the Barnsley Coal.

In the preparation of the maps use has been made of the information supplied by the numerous colliery sinkings to the west. A certain amount of generalization of the beds has been necessary ; sporadic thin sandstones have been ignored, and no attempt has been made to follow the outcrops in the exposed ground.

SANDSTONES ABOVE THE TOP MARINE BED

Three main sandstone horizons can be made out in the 1,000 ft.-1,500 ft. of Middle Coal Measures that lie above the Top Marine Bed. It is interesting to note that some of these sandstones have been found to possess a reddish or purple colour when they have been met with in some of the borings in Nottinghamshire.

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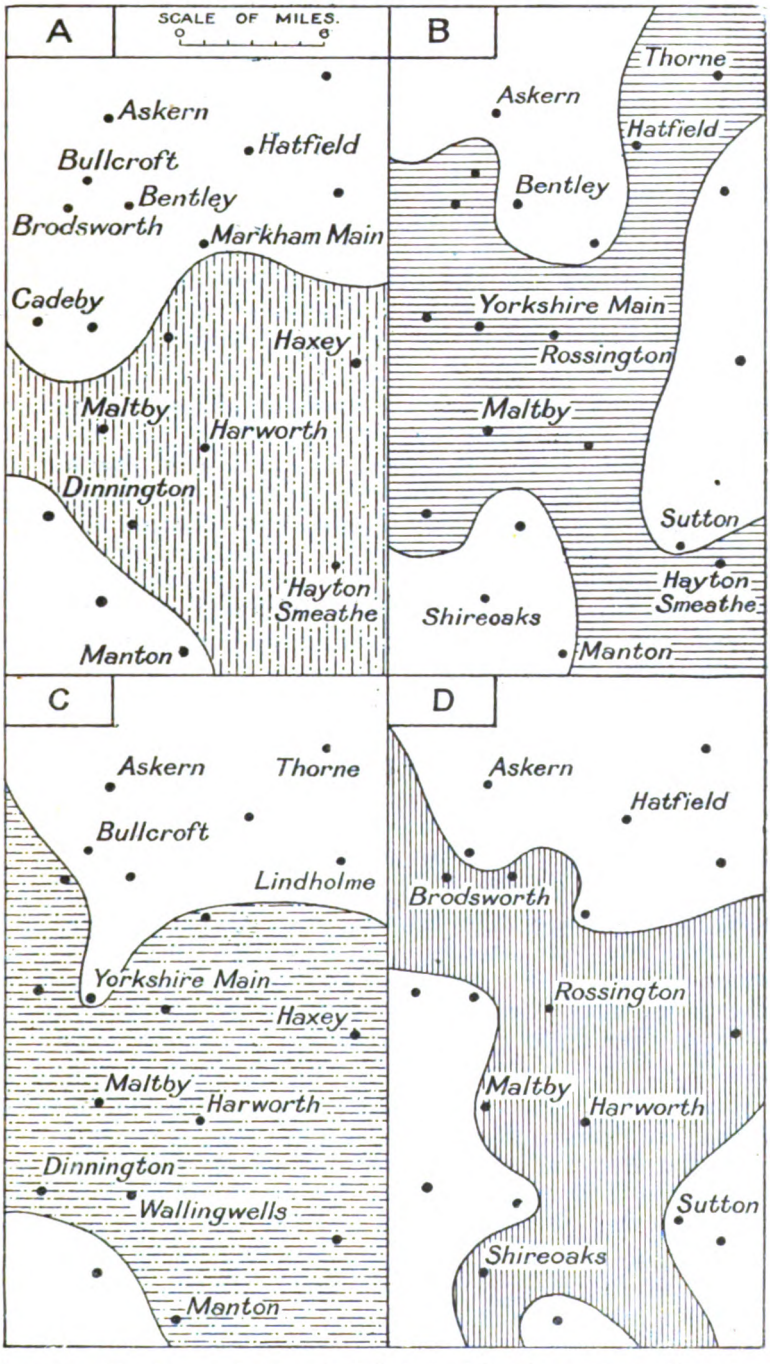

FIG. 1.—*Sketch-map showing Distribution of Sandstones in northern part of the Concealed Coalfield of Yorkshire and Nottinghamshire.*

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The uppermost of the sandstones occurs some 700 ft.—1,000 ft. above the Top Marine Bed. In the area covered by the maps this rock has only been noted at Maltby and Wallingwells. In the north-west, however, a sandstone was encountered in the sinking at Upton, and the well-known Pontefract or Wickersley Rock must occur somewhere about this position.

Sandstone A (Fig. 1).—This horizon is well developed in the area between Maltby, Haxey and Hayton Smeathe where it averages 120 ft. in thickness. It is present at Thurcroft in the west, but is missing at Dinnington. The highest Coal Measures encountered at Shireoaks and Manton lie below this horizon. In the exposed coalfield a sandstone at about this position is known as the Ackworth or Brierley Rock.

Sandstone B (Fig. 1).—In the northern part of the area, from Thorne round by Yorkshire Main to Bullcroft, the thickness of this horizon is about 100 ft. It expands to 200 ft. at Maltby but thins off towards Harworth. No well developed bed of sandstone occurs at this position at Sutton, but 150 ft. was recorded at Hayton Smeathe. Further south the highest Coal Measures present in the boring at Boughton are above this horizon. It is difficult to correlate this sandstone with any definite bed in the exposed coalfield, but beds near this position are known as the Great Houghton Rock and the Havercroft Rock.

SANDSTONES BETWEEN THE TOP MARINE BED AND THE MANSFIELD MARINE BED

Three sandstone positions can be recognised in the 450 ft.—550 ft. of strata that intervene between the Mansfield and the Top Marine Beds. In some instances the thickness of the sediments of sandy type attains to about 200 ft.

Sandstone C (Fig. 1).—This horizon is thickest near Dinnington where it averages about 200 ft. It is absent at Yorkshire Main, but varies from 80 ft.—100 ft. in thickness over most of the area shown on the map. Further south at Boughton near Ollerton the thickness has diminished to about 50 ft. The sandstone known as the Upper Chevet Rock occurs at about the same position in the sequence.

Sandstone D (Fig. 1).—A sandstone at this horizon is well developed at Hemsworth and Nostell to the west of the area. Over most of the district it is only about 50 ft. in thickness, and it is not readily recognised in the ground to the south. Near Cudworth a sandstone at this position is known as the Middle Chevet Rock.

Sandstone E (Fig. 2).—This horizon averages from 50 ft.—70 ft. in thickness over most of the area, but expands to over 150 ft. at Thorne, Hatfield and Yorkshire Main. It is the first thick sandstone above the Mansfield Marine Bed, and in many bore journals and shaft-sections has been recorded as the Oaks Rock. It appears however, that this identification is not correct ; since at Cudworth

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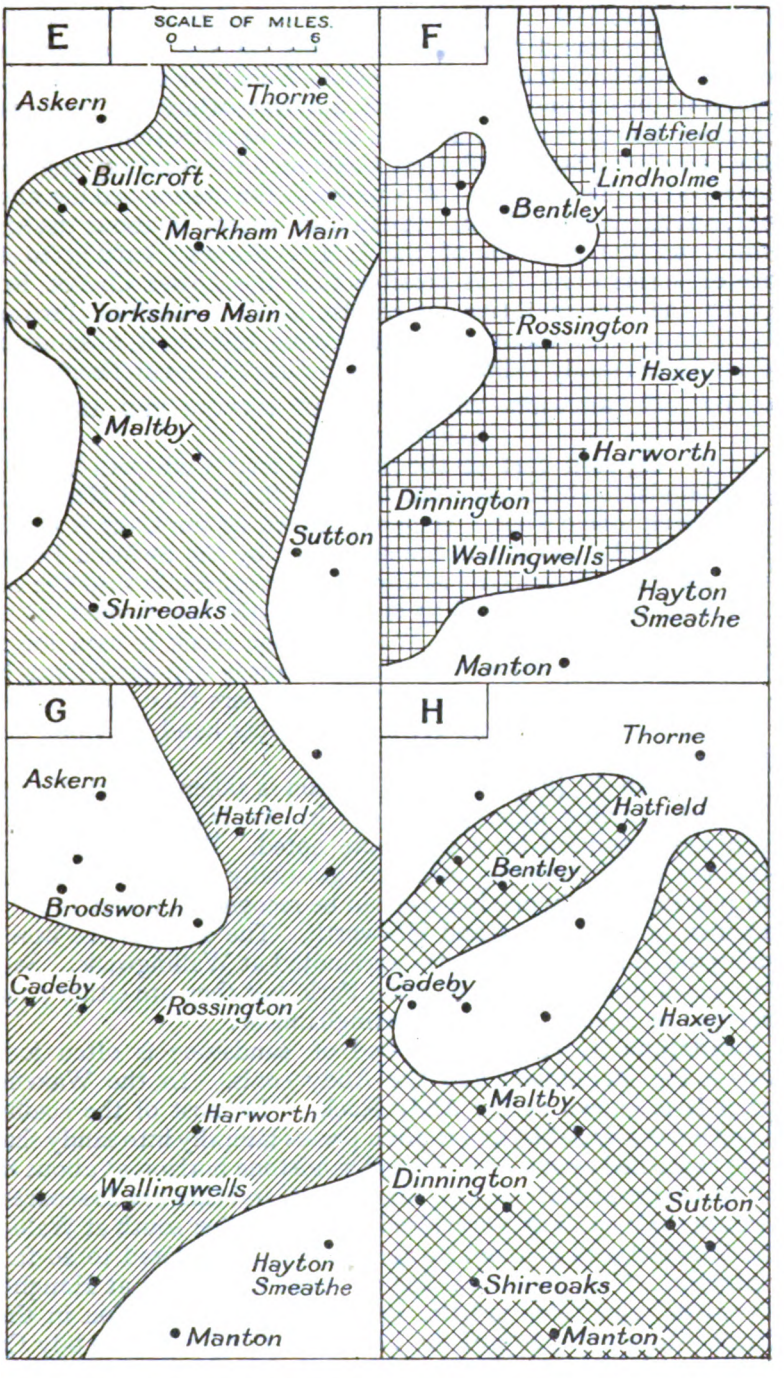

FIG. 2.—*Sketch-map showing Distribution of Sandstones in northern part of the Concealed Coalfield of Yorkshire and Nottinghamshire.*

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and near Wakefield[1], a bed which is considered to be the Mansfield Marine Bed is found to occur above the Oaks Rock of the Oaks district. Recently the base of the Oaks Rock was exceedingly well exposed in the cutting on the L.M.S. Railway, which has been made to replace the Chevet Tunnel. A careful examination of the roof of the underlying Swinton Pottery Coal failed to reveal any trace of a marine bed at this position. At Cudworth the marine bed lies about 200 ft. above the Oaks Rock. It can also be seen in about the same position on the east side of the L.M.S. Railway cutting to the south of Normanton. It is possible that the Lower Chevet Rock may be the representative of Sandstone E. South of Harworth this horizon is only about 50 ft. in thickness, but 100 ft. of sandstone and associated sandy sediments occur in this position at Thoresby.

SANDSTONES BETWEEN THE MANSFIELD MARINE BED AND THE BARNSLEY COAL

In the exposed part of the coalfield near Cudworth two well defined sandstone horizons occur between the Mansfield Marine Bed and the Meltonfield Coal. They are known as the Oaks Rock and the Woolley Edge Rock, and are separated by the Swinton Pottery Coal. As they are traced eastwards and southwards into the concealed area their individuality is lost, and in the Memoir on the Concealed Coalfield the name Woolley Edge Rock is used for the sandstone in this position. In some instances two sandstones can be recognised; as for instance at Maltby, where they are separated by a marine bed. At Dinnington, on the other hand, only one thick sandstone occurs.

Sandstone F (Fig. 2).—This horizon is taken as including the Oaks and Woolley Edge positions. In the Hatfield section two sandstones separated by a coal were noted. When traced south-westwards the intervening measures gradually become more sandy until practically only one horizon can be recognised, about 150 ft. in thickness, at Rossington and Harworth. The same is the case at Dinnington, but two sandstones were noted at Wallingwells. Sandstones occur in this zone at Kiveton Park, but they are either poorly developed or absent in South Nottinghamshire.

Sandstone G (Fig. 2).—A bed of sandstone is often found between the Meltonfield and the Abdy coals. In the Wakefield district it is known as the Abdy Rock. In most of the coalfield the bed is very variable, and it often passes laterally into sandy shale. In the concealed area a well marked sandstone horizon at about this position occurs at Hatfield and Rossington, and thin bands separated by sandy shale occur at Yorkshire Main. Further south at Wallingwells the thickness is about 80 ft. but it has decreased to 20 ft. at Dinnington. The Abdy Coal has not been recognised at Haughton and Sutton, and there is little sandstone in this position in these borings. In many parts of the Concealed Coalfield the Abdy Coal

[1] 'The Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 1926, p. 33, also 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 62 and 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), 1928, Pt. I, p. 46.

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has been recognised by the presence of marine fossils in the roof shales, and in other localities the name has been given to a coal with cannel in the roof. The examination of a large number of graphically drawn-up sections of bores and shafts shows, that either there is a great variation in the character of these measures between neighbouring localities, or that the name has not always been applied to the same seam. For instance a well defined thick sandstone horizon occurs in what is considered the same part of the sequence at Cadeby, Yorkshire Main and Rossington. The collieries are in a line and the distance from Cadeby to Rossington is about 6 miles. At the latter locality the Abdy with its marine roof occurs below this sandstone, but at Cadeby the name is given to a seam above it.

Sandstone H (Fig. 2).—This horizon is taken as including the sandstones between the Abdy and the Kents Thick or High Hazel coals. (At Cadeby the coal at 1896 ft. is taken as representing the Abdy of Rossington, and not the one named the Abdy at 1,736 ft.). The horizon is well developed at Bentley, where it is about 120 ft. thick, but over most of the area it averages 30 ft. At Haxey and Sutton a great deal of sandy sediment comes in at this part of the sequence, but there is none recorded at Crosby. Further south usually there is little sandstone in this position.

SANDSTONES BELOW THE KENTS THICK OR HIGH HAZELS COAL

Two thin sandstone horizons, averaging about 20 ft. in thickness often occur in this part of the sequence. The upper one generally is to be found a short distance below the Kents Thick Coal, and the lower one occurs not far above the Barnsley or Top Hard Coal. It is sometimes known as the Barnsley Rock. In Kirkby Lowmoor Shaft a sandstone about 70 ft. in thickness occurs in this position.

An examination of the maps brings out certain points of interest. It will be noticed for instance that most of the beds are well developed in the central area around Maltby and Harworth, and that all of them are absent at Askern.

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VIII.—UPTON COLLIERY SINKING

By G. V. Wilson, B.Sc. and D. A. Wray, Ph.D., M.Sc.

Text-figure 1.

The examination of the materials of this sinking has thrown a great deal of light on the geological sequence and structure in this part of Yorkshire. Through the courtesy of Mr. R. Graham we were permitted to watch the operations from their commencement. We also received much valuable help from Messrs. W. Dallas and A. G. Lole.

The colliery is situated at Upton, on the western edge of the outcrop of the Magnesian Limestone, and about half-way between Doncaster and Pontefract. An examination of the ground shows the presence of a fault which throws down the base of the Magnesian Limestone from the outcrop on Upton Beacon, to near the site of the shafts. The difference in level is about 50 ft. In the sinking of the East or No. 1 shaft a zone of highly inclined measures was encountered between the depths of 140 ft. and 375 ft., and disturbed strata occurred from 60 ft. to 420 ft. Above and below these depths the dip of the measures was similar to that in the West or No. 2 Shaft. The strike of the upturned beds is north-east and the dip averages about 70 degrees. This implies that the true thickness of the 235 ft. of highly inclined beds is only about 85 ft. The two shafts are 60 yds. apart, and the line of movement passes between them. It was not possible to correlate with accuracy any of the beds in or above the disturbed zone with those in the West Shaft. Below that position, however, the sequence is practically the same in both shafts. A coal 13 in. thick in the East Shaft at 516 ft. is considered to be the same as one 14 in. thick at 507 ft. in the West Shaft. The Shafton Coal, 3 ft. thick, occurs at 896 ft. in the East Shaft and 883 ft. in the other, and the Mansfield Marine Bed is at about 1,380 ft. in both shafts.

There is no doubt that a great displacement of the measures takes place along this line of movement, but it is difficult to say what the amount is. A minimum figure can be arrived at by adding the 50 ft. which the base of the Magnesian Limestone is known to be displaced, to the 150 ft. which represents the difference between the true and the apparent thickness of the measures in the highly disturbed zone. This gives a figure of 200 ft. The diagram (Fig. 1) shows a possible representation of the geological structure of this line of movement.

In the sinking of the West Shaft a thick mass of sandstone was encountered at the surface. This yielded as much as 1,200 galls. of water per minute and greatly impeded the operations.

In the West Shaft the Top Marine Bed was well marked at 852 ft.

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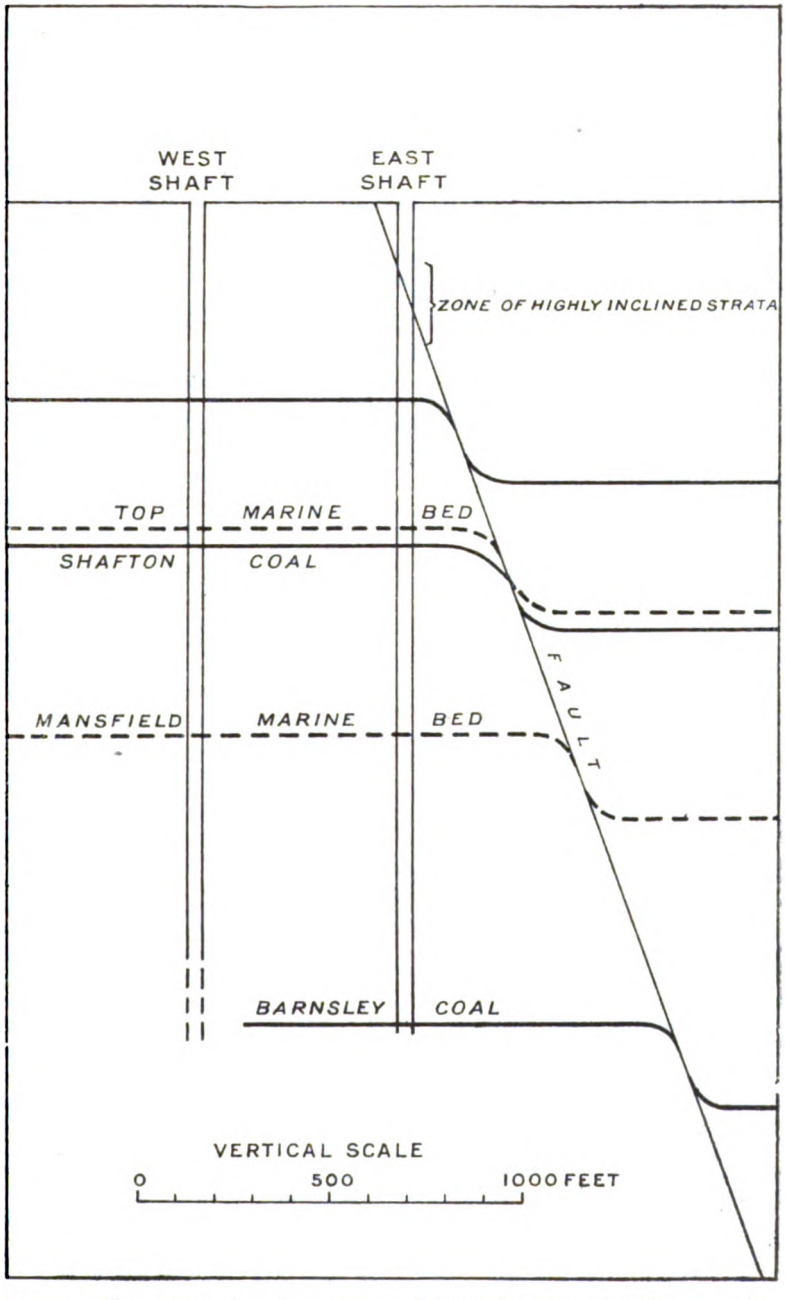

FIG. 1.—*Diagram to show the possible relations of the fault at Upton Colliery.*

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It yielded *Pterinopecten, Ctenodonta, Lingula*, a nautiloid and numerous fucoid markings. The Mansfield Marine Bed occurred 528 ft. lower at 1,380 ft. There was no cank, and the fossils, which were scarce, were similar to those from the Top Marine Bed with the exception that fragments of goniatites occurred, and no nautiloid was noticed.

The distance between the Mansfield Marine Bed and the Barnsley Coal is 751 ft., or 25 ft. less than would have been expected from an examination of the map shown in the *Summary of Progress* for 1925.[1]

The upper part of the detailed section given below is taken from the West Shaft down to the position of the coal at 507 ft., which is taken as being the same as that at 516 ft. in the East Shaft.

Upton Section

One-inch Sheet (N.S.) 78 ; Six-inch Map, Yorks. 264 N.W.
Communicated by Mr. R. Graham.
Heights above O.D., West Shaft 199.2 ft. ; East Shaft 209 ft.
(Slightly abridged).

	Thickness.		Depth.	
	Ft.	In.	Ft.	In.
Top portion (West Shaft).				
Clay	—	—	—	—
Sandstone	—	—	65	3
Coal and dirt	5	10	71	1
Fireclay	4	2	75	3
Sandstone	17	10	93	1
Coal	—	**2**	**93**	**3**
Fireclay	2	9	96	0
Bind with ironstone nodules	26	10	122	10
Sandstone	1	9	124	7
Fireclay	1	8	126	3
Coal	—	**9**	**127**	**0**
Bind and fireclay	27	5	154	5
Sandstone	6	3	160	8
Bind and shale	21	2	181	10
Sandstone and sandy bind	14	9	196	7
Black shale and fireclay	1	7	198	2
Coal	—	**2**	**198**	**4**
Blue and black shale	50	2	248	6
Sandstone	9	10	258	4
Stone bind	21	7	279	11
Black shale, coal and fireclay	1	9	281	8
Sandstone and sandy shale	14	10	296	6
Shale and fireclay	35	3	331	9
Stone bind	13	10	345	7
Coal and bat	**1**	**10**	**347**	**5**
Clunch	4	1	351	6
Stone bind and clunch	11	1	362	7
Coal	—	**3**	**362**	**10**
Stone bind	10	11	373	9
Coal and black shale	—	7	374	4
Bind and clunch...	6	8	381	0
Coal	**1**	**0**	**382**	**0**
Clunch and stone bind	10	3	392	3
Clunch and black shale	3	9	396	0

[1] 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 61.

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	Thickness. Ft.	In.	Depth. Ft.	In.
Coal	—	8	**396**	**8**
Grey and dark bind and clunch	59	6	456	2
Sandstone and stone bind	18	11	475	1
Coal and fireclay	—	5	475	6
Sandstone and stone bind	30	5	505	11
Coal (At 516 ft. 8 in. *in the East Shaft*) ...	**1**	**2**	**507**	**1**
Bottom portion (East Shaft).				
Coal	**1**	**1**	**516**	**8**
Fireclay, bind and stone bind	32	2	548	10
Sandstone	12	2	561	0
Stone bind	8	11	569	11
Coal	**1**	**4**	**571**	**3**
Fireclay, clunch and stone bind	19	4	590	7
Coal	—	**7**	**591**	**2**
Stone bind	11	4	602	6
Coal and clunch	1	5	603	11
Clunch and stone bind	7	4	611	3
Sandstone and stone bind	89	9	701	0
Blue and grey bind	10	4	711	4
Stone bind with sandstone ribs	37	5	748	9
Blue bind	10	9	759	6
Stone bind and clunch	28	10	788	4
Coal and dirt	—	9	789	1
Clunch and stone bind	13	10	802	11
Coal	—	**6**	**803**	**5**
Blue bind (TOP MARINE BED at the base)	48	11	**852**	**4**
Stone bind	28	6	880	10
Sandstone	10	10	891	8
Black bind	1	5	893	1
Coal (SHAFTON)	**3**	**3**	**896**	**4**
Clunch	1	4	897	8
Coal and fireclay	1	5	899	1
Stone bind and sandstone bands	8	8	907	9
Blue and black bind	10	2	917	11
Coal	—	2	918	1
Sandstone	85	3	1,003	4
Coal	—	**9**	**1,004**	**1**
Stone bind and sandstone	64	7	1,068	8
Black bind	11	7	1,080	3
Coal	**2**	**9**	**1,083**	**0**
Strong clunch	10	9	1,093	9
Blue bind and stone bind	25	4	1,119	1
Sandstone	45	8	1,164	9
Coal dirt and clunch	5	4	1,170	1
Sandstone	63	1	1,233	2
Blue bind	12	3	1,245	5
Coal 1ft. 5 in., dirt 3 in., coal 1 ft.	**2**	**8**	**1,248**	**1**
Clunch and bind...	24	7	1,272	8
Stone bind with sandstone ribs	88	3	1,360	11
Blue bind with ironstones nodules (MANSFIELD MARINE BED)	**19**	**1**	**1,380**	**0**
Dark bind	1	11	1,381	11
Coal 2 in., clunch	4	1	1,386	0
Bind and stone bind	33	8	1,419	8
Coal	—	1	1,419	9
Clunch	5	8	1,425	5
Stone bind and blue bind	74	6	1,499	11

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	Thickness. Ft.	In.	Depth. Ft.	In.
Blue and black bind	11	0	1,510	11
Clunch, stone bind and sandstone	12	8	1,523	7
Blue bind	11	7	1,535	2
Coal	**1**	**9**	**1,536**	**11**
Clunch	6	1	1,543	0
Blue bind...	8	11	1,551	11
Sandstone and stone bind	25	5	1,577	4
Blue bind	19	0	1,596	4
Stone clunch	5	8	1,601	0
Blue and black bind	8	0	1,609	0
Coal	—	**9**	**1,609**	**9**
Clunch	3	0	1,612	9
Stone bind	22	3	1,635	0
Blue bind	15	6	1,650	6
Stone bind	25	5	1,675	11
Blue and black bind	13	9	1,689	8
Coal 1 ft. 7 in., dirt 7 in., Coal 1 ft. 10 in. ...	**4**	**0**	**1,693**	**8**
Clunch and bind...	20	4	1,714	0
Coal	**1**	**6**	**1,715**	**6**
Clunch	1	10	1,717	4
Sandstone and stone bind	21	0	1,738	4
Coal	**1**	**4**	**1,739**	**8**
Clunch, stone bind and sandstone	15	6	1,755	2
Bind	11	3	1,766	5
Coal	**2**	**5**	**1,768**	**10**
Clunch	6	3	1,775	1
Sandstone	12	1	1,787	2
Mussel Bed	—	3	1,787	5
Coal (Cannel)	—	**4**	**1,787**	**9**
Stone bind	22	3	1,810	0
Black bind	8	8	1,818	8
Coal 3 in., clunch	5	0	1,823	8
Stone bind and dark bind	20	10	1,844	6
Coal, good	**2**	**8**	**1,847**	**2**
Clunch and stone bind	19	5	1,866	7
Bind	16	8	1,883	3
Coal	—	**4**	**1,883**	**7**
Clunch	7	7	1,891	2
Stone bind	2	0	1,893	2
Coal 1½ in., clunch.	8	0	1,901	2
Bind and stone bind	26	7	1,927	9
Coal	**1**	**2**	**1,928**	**11**
Clunch	4	10	1,933	9
Stone bind	8	4	1,942	1
Blue bind	17	3	1,959	4
Mussel Bed	—	1	1,959	5
Coal (Cannel)	**2**	**0**	**1,961**	**5**
Clunch and bind...	13	2	1,974	7
Coal	—	**8**	**1,975**	**3**
Clunch	2	7	1,977	10
Blue bind	23	7	2,001	5
Stone bind	14	8	2,016	1
Coal and bind	—	3	2,016	4
Clunch and stone bind	18	4	2,034	0
Blue bind	28	2	2,062	2
Clunch	5	4	2,067	6

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	Thickness. Ft.	In.	Depth. Ft.	In.
Coal 1 in., black bind	—	8	2,068	**2**
Stone bind	50	1	2,118	**3**
Coal ...	**2**	**0**		
Clunch	2	0		
Coal	—	**5**		
Shale ... BARNSLEY COAL ...	—	10		
Coal (Top)	**3**	**9**		
Dirt	—	10		
Coal (Bottom)	**4**	**11**	**2,133**	**0**
Clunch				

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IX.—ON THE GLACIATION OF THE NORTH COTTESWOLD AREA.

By H. G. DINES, A.R.S.M.

Text-figure 1.

The mode of occurrence of the drift in the North Cotteswolds has long been a subject of controversy, and in the absence of a systematic survey, theories put forward have been largely a matter of speculation. An examination of the various classes of superficial deposits present has led some observers to postulate glaciation of the district : some, however, have favoured the idea of submergence, while others maintain that the drift represents the remains of solid strata formerly extending over the area.

A comprehensive review of the literature dealing with the subject is given by J. W. Gray,[1] from whose papers one gathers that Buckland was the first to give attention to the area, and in 1821 [2] recorded the presence of drift in the Vale of Moreton, which he assumed to have been deposited by a stream from the north passing down the valley of the Evenlode into that of the Thames. This view is substantially correct, though Buckland, after the manner of his time, attributes the agency of transportation of the material to " the last great deluge that has overwhelmed the earth."

In dealing with traces of northern drift that occur on the uplands of the Cotteswolds, Lucy [3] suggests that their presence is due to the agency of ice. The red-brown clay with northern pebbles that occurs so commonly as an infilling of surface fissures in the limestones he terms ' Boulder Clay,' an expression which does not appear to have been accepted by contemporary and some later writers, who disclaim, without giving adequate reasons for doing so, that the presence of clay with northern pebbles in the fissures affords evidence of glaciation.[4] In some cases, spreads of boulder-clay rightly diagnosed by Lucy, have been regarded as clayey soils, resulting from the decomposition of calcareous beds *in situ*.

The proximity of the northern ice to the Cotteswolds is generally accepted as being responsible for the presence of northern pebbles in the area, but the southern limit of the Boulder Clay has not been traced with any degree of certainty in the western part of England. It is generally assumed to have followed roughly the northern flank of the Thames valley and to have extended westward in a curve around the northern ends of Edge Hill, the Cotteswolds and Bredon Hill, all of which have hitherto been regarded as barriers which

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[1] *Proc. Cotteswold Nat. Field Club*, vol. xvii, 1910-12, pp. 257-274 ; vol. xx, 1919, pp. 99-141.
[2] *Trans. Geol. Soc.*, vol. v, 1821, pp. 516-544.
[3] *Proc. Cotteswold Nat. Field Club*, vol. vi, 1872, p. 19 ; vol. vii, 1878, pp. 50-61 ; vol. x, 1889, p. 7.
[4] Woodward, H. B., *Geol. Mag.*, 1897, p. 487 ; Gray, J. W., *Proc. Cotteswold Nat. Field Club*, vol. xx, 1919, p. 109.

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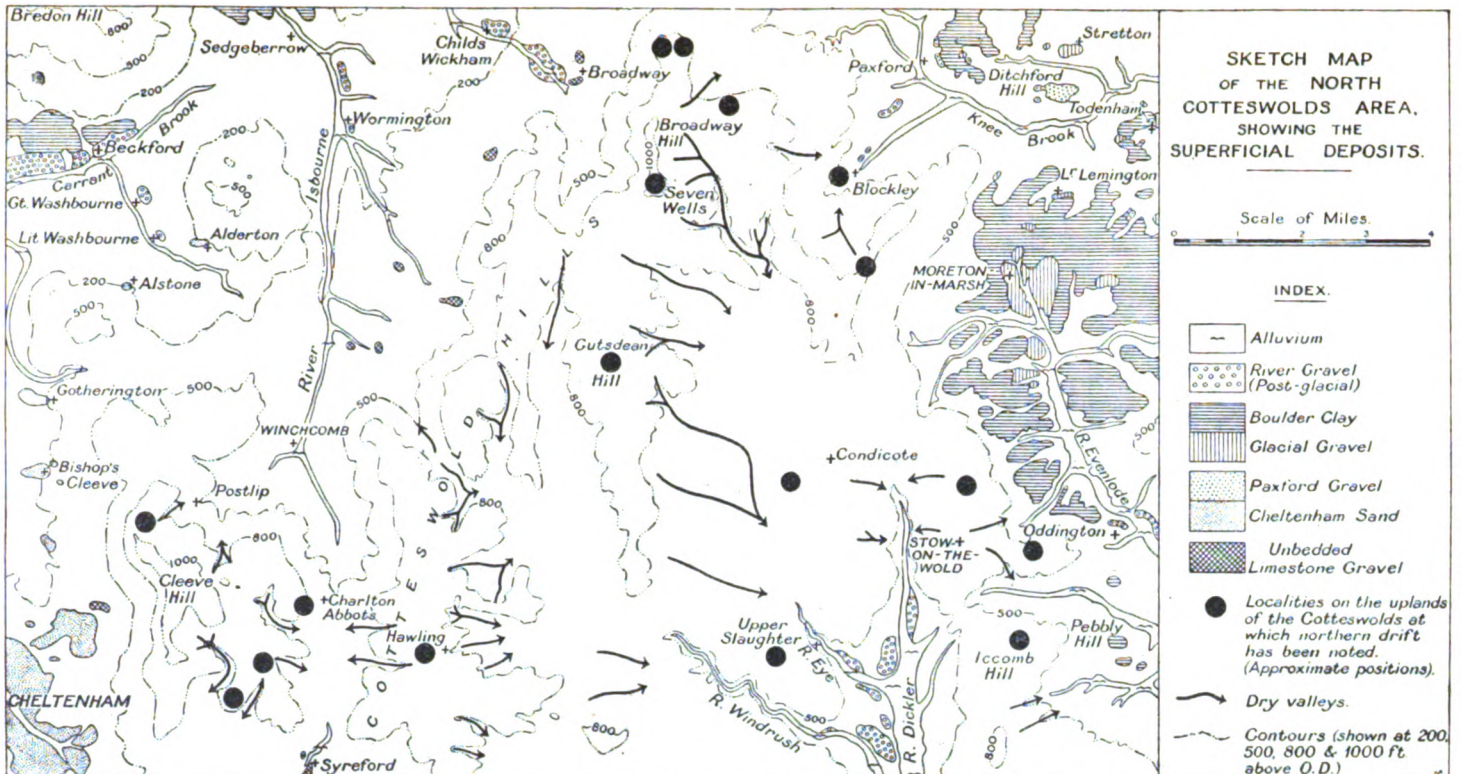

FIG. 1.

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arrested the southward progress of land glaciation. Woodward, however, on the evidence of sections, at Mickleton and Aston Magna, recorded by Gavey in 1853, has suggested the possibility of a tongue of boulder-clay projecting southward into the Vale of Moreton,[1] and Dr. C. Callaway recognised Glacial Clay on the Cotteswolds at Tangley as well as in the valley at Milton-under-Wychwood.[2]

A recent survey of the drift of the district covered by the one-inch Ordnance map Sheet 217 (Moreton-in-Marsh) shows that the glacial deposits definitely form the bulk of the superficial deposits of the area. Boulder-clay and glacial gravel occur extensively in the Vale of Moreton and extend southward along the valley of the Evenlode, while on the western side of the area boulder-clay occurs to the east and south of Bredon Hill. Drift deposits of local origin are not extensive but their relation to the Glacial deposits is in most cases a matter of certainty.

The Vale of Evesham.—In that part of the Vale that lies between Bredon Hill, Broadway and Cheltenham there are four types of deposits:—(1) Unbedded Limestone Gravel, (2) 'Cheltenham Sand' associated with limestone-gravel, (3) Boulder Clay, (4) River Gravel (post-Glacial).

1.—The Unbedded Limestone Gravel consists of angular and subangular debris, from the hills, accumulated on the lower slopes generally at about the 300-ft. contour. It is composed entirely of local material and shows no sign of bedding. The matrix, which forms a small proportion of the whole, is mainly comminuted limestone material. This deposit was probably a source of supply of the limestone constituent of the Cheltenham Sand and the river-gravels, though some of the spreads of the Unbedded Gravel may be of later date.

2.—The Cheltenham Sand is mainly a pale buff quartzose sand with layers of limestone-gravel. The sand is coarser than any known Jurassic sand in the neighbourhood and on the evidence of the suite of heavy minerals yielded, Dr. H. H. Thomas infers that the Trias furnished most of the material[3]; the pebbles present however are all of local origin. This deposit covers a large area at Cheltenham and occurs in small patches at Bishop's Cleeve, Gotherington, Alstone and Alderton. These occurrences are at a uniform level of 200 ft. above O. D. though in the Cheltenham neighbourhood, where the deposit attains its greatest thickness, it rises to higher levels.

3.—The Boulder Clay occurs below the 200-ft. level in patches north of Sedgeberrow and at Beckford, while the intervening ground is strewn with *remanié* drift. The clay is not exposed in any section here but the red loamy soil with northern pebbles and boulders is evident on the surface of cultivated areas.

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[1] *Op. cit.*, p. 487.
[2] *Geol. Mag.*, 1905, pp. 216-219.
[3] Richardson, L., 'Memoir Explanatory of a Map of a Part of Cheltenham,' *Proc. Cotteswold Nat. Field Club*, vol. xvii, 1910-12, p. 305.

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4.—The post-Glacial River Gravel occurs at Broadway, Childs Wickham, Wormington, the Washbournes and Beckford. It consists of current-bedded sand and gravel, the latter composed mainly of limestone pebbles but with some northern material. At Beckford in the valley of the Carrant Brook this gravel lies directly on the boulder-clay.

The Vale of Moreton.—Here the deposits are (1) Paxford (limestone) Gravel, (2) Glacial Gravel, (3) Boulder Clay, and (4) River Gravel (post-Glacial).

1.—The Paxford Gravel, a compact-bedded deposit of limestone fragments, underlies the Glacial deposits and contains no northern pebbles. At Paxford and Ditchford Hill it is entirely of local origin without quartz sand. At Paxford the gravel is overlain by boulder-clay, here a homogeneous red-brown plastic clay with northern pebbles and boulders, while fissures in the gravel at Ditchford Hill contain similar clay and pebbles. Near Great Wolford, 1½ miles east of Lower Lemington, the gravel of this period resembles the Cheltenham Sand, having a large proportion of quartz sand with layers of limestone-gravel. This is overlain by at least 10 ft. of glacial gravel.

2.—Glacial Gravel occurs at Mickleton, Stretton, Todenham, Wolford, around Moreton-in-Marsh, and a mile to the east, at the Four Shire Stone. At Stretton it consists of coarse pink current-bedded sand with thin streaks of Bunter quartzite and quartz pebbles and some small subangular flints. It is overlain by boulder-clay which is pocketed irregularly into the upper surface. The spreads at Todenham and Wolford are similar. The Moreton gravel [1] is typical glacial gravel, the upper part of which has been disturbed by the over-riding ice, giving rise to a vertical arrangement of some of the pebbles.

3.—Boulder Clay once extended as a practically continuous sheet at a level of 400-450 ft. O.D. down the Vale of Moreton but has since been dissected by the Knee Brook, the Evenlode and its tributaries. It occurs between Paxford and Stretton and at Todenham, and covers practically the whole of the floor of the Evenlode valley from Lower Lemington to Oddington. Southward of this the clay occurs in smaller patches near Bleddington and at Pebbly Hill. It has been recorded as far south as Milton-under-Wychwood.[2] Sections near Paxford show a homogeneous plastic red-brown or purple clay with scattered northern stones in which Bunter pebbles, quartz and flint predominate. The Bunter quartzite and the quartz usually occur as small pebbles but boulders are of frequent occurrence; the flints also are mainly small but some large unworn specimens are not uncommon. The lower part of the Boulder Clay, as seen at Mickleton, at Black Downs, 1½ miles east-by-north of Paxford, near Paxford and at Stretton consists in places

[1] Reade, T. M., S. S. Buckman and C. Callaway, *Proc. Cotteswold Nat. Field Club*, vol. xiv, 1903, pp. 111-118.
[2] Callaway, C., *op. cit.*

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of a chaotic mass of blocks of local limestone up to a foot or more across, mixed in a clayey matrix with smaller northern stones and rafts of the red plastic clay. In all localities in which boulder-clay and glacial gravel occur, the former overlies the latter.

4.—The post-Glacial River Gravels occur in the valley of the Knee Brook at Blockley and in the valleys of the Dickler, Windrush and Eye to the south of Stow-on-the-Wold. These are mainly limestone-gravels, and owing to their positions in valleys separated from the main spreads of boulder-clay by high ground, they do not contain much northern material, though the deposits south of Stow-on-the-Wold are reported to contain a few scattered flint fragments. At Oddington, however, the river gravels of the Evenlode are well bedded and contain a fair proportion of quartz sand as well as an abundance of northern stones.

The Uplands.—The northern part of the Cotteswolds, does not appear to have been covered with any considerable thickness of boulder-clay, but the fact that the northern ice rode up over the hills is evident from the numerous recorded occurrences of northern pebbles on the high ground, and the infillings of red-brown clay with northern pebbles that are frequently to be seen in fissures in the limestones, as at Tangley (625 ft. above O.D.) and Martin's Hill (600 ft. above O.D.), a mile east of Stow-on-the-Wold and elsewhere. Known occurrences of northern drift on the high ground extend as far south as Tainton Down, near Burford. A deposit of clay with northern stones occurs at Hill Farm (700 ft. above O.D.) a mile west of Upper Slaughter,[1] and it is possible that there are unrecorded occurrences elsewhere. Northern pebbles sufficient to cobble the path at the Snowshill Road Lodge at Springfield are said to have been collected on the fields between the Lodge and Seven Wells (1,048 ft. above O.D.).

Further evidence of glaciation of the uplands is afforded by the fact that many of the exposures in the limestones show but little weathered rock ; this according to Woodward is favourable though not conclusive evidence of glaciation.[2] Where the weathering extends to a depth of several feet, however, the loosened slabs of limestone are much disturbed, as at Martin's Hill. Moreover the slopes of the Cotteswolds are covered, in many localities with accumulations of rubble which at Syreford has a matrix of brown loamy clay. This rubble probably accumulated on the hill slopes during times of thaw. Again many of the valleys cutting through the limestone are now dry. They commence in the higher parts of the country where no source of water-supply is now available and, from a flat plain, plunge steeply down into deep gorge-like valleys, dry for a considerable length in their upper reaches. These valleys may be due, in part, to solution of the limestone, but it is possible that water from a melting snow- or ice-cap may have played a part

[1] Gray, *op. cit.*, vol. xvii, 1911, pp. 260-261.
[2] *Op. cit.*, p. 490.

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in the formation of some of them, for example, the Postlip valley, and that which commences near the slopes of Broadway Hill on the western side of the Cotteswolds and runs in a direction south-south-east as a steep-sided valley which is dry for about five miles before it becomes occupied by the River Dickler.[1]

Conclusion.—There is no suggestion of the glaciation of the Cotteswolds having been severe ; the boulder-clay in the Evenlode valley, though widespread, does not appear to exceed 8 ft. in thickness, and the presence of boulders of limestone in the base of the boulder-clay, as at Mickleton, Black Downs and Stretton, indicates that accumulations of disintegrated local rocks contained in the local sedentary ice-sheet, though absorbed by the advancing ice-sheet from the north, had not travelled sufficiently far to become incorporated in the higher part of the drift. The absence of thick or large spreads of boulder-clay on the uplands can be accounted for by the probability that only the higher portions of the ice-sheet over-rode the hills.

[1] See also Buckland, *Trans. Geol. Soc.*, vol. v, 1821, p. 523, footnote.

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X.—A NOTE ON 'PTYGMATIC FOLDING' IN THE SUTHERLAND GRANITE-COMPLEX

By H. H. Read, D.Sc., A.R.C.Sc.

Text-figures 1 and 2.

During his life-study of the Finnish granite-complexes, Professor J. J. Sederholm has suggested many new terms for the remarkable structures and associations there encountered; among these is *ptygmatic folding*. A tracing (Fig. 1, upper) of an illustration from the latest publication of Sederholm will serve to show the nature of ptygmatic folding better than words.

In a long series of investigations[1], Sederholm has discussed the origin of this structure. His results may be briefly summarised as follows. Ptygmatic folding is illustrated typically by acid veins connected with granite injections. From the absence of metamorphism in the minerals of the veins, it is considered that the consolidation of the vein took place, in general, subsequent to the folding. The veins were probably all originally straight and filled plane fissures in the rock. Their characteristic folding is due to undulating movements in the softened or semi-molten country-rock, this softening arising from the associated granite injections.

Other observers of what are certainly ptygmatically folded veins have not accepted Sederholm's explanation. Among these, two divergent opinions are maintained; the first due to P. J. Holmquist, sees in the formation of ptygmatically folded veins the operation of ultrametamorphism; the second, advanced by L. Milch, B. Sander, J. E. Spurr and others, would explain ptygmatic structure as due to folding of 'Alpine type' produced by mountain-building movements after the consolidation of the vein-substance.

While he admits the local occurrence of injection-rocks related to definite granite intrusions, P. J. Holmquist[2] regards the more regional veined rocks (Adergesteine) as the result of ultrametamorphism,—the production from the substance of the rock undergoing regional metamorphism of its own secreted endogenous pegmatites. Under the conditions of ultrametamorphism such secreted pegmatites take up a contorted form in the plastic country-rock, which though plastic enough to follow the plications of the pegmatite, is not itself deformed in a corresponding manner. Among the other group of observers, L. Milch[3] concludes that the form of

[1] Sederholm, J. J., 'Om Granit och Gneis', *Bull. Com. Géol. Finlande*, No. 23, 1907; 'Uber ptygmatische Faltungen,' *Neues Jahrb.* B. Bd. 36, 1913, p. 491; 'On Migmatites and Associated pre-Cambrian Rocks of Southwestern Finland, I—the Pellinge Region,' *Bull. Com. Géol. Finlande*, No. 58, 1923, and 'II—the Region around the Barosundsfjard W. of Helsingfors, etc.,' *ibid*, No. 77, 1926.

[2] Holmquist, P. J., 'Typen und Nomenklatur der Adergesteine,' *Géol. Foren. Forh.*, xliii, 1922, p. 612; 'Om Pegmatitpalingenes och ptygmatisk Veckning,' *ibid.*, xlii, 1920, p. 191.

[3] Milch, L., 'Ueber dynamometamorphe Erscheinungen an einem nordischen Granitgneis,' *Neues Jahrb.*, ii, 1900, p. 39.

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ptygmatic veins in a German erratic originating from Scandinavia is obviously secondary, produced by pressure affecting the rock after its solidification; where the veins in this specimen are hazy, Milch considers them to have been partly obliterated by the movements. Again, B. Sander,[1] after visiting the Finnish examples, maintained that they were the results of folding of "Alpine type" and could be matched in Alpine specimens unassociated with regional injection or anatexis. Recently, too, J. E. Spurr[2] has described and figured from Manitoba typical ptygmatic veins (accepted as such by Sederholm) which he believes to be the effect of gneissic deformation, resulting in the folding of each vein "back on itself like an accordion,

FIG. 1.—*Veins showing 'Ptygmatic Folding,' from Finland (above) and Sutherland (below).*

regularly, showing a uniform compression at right angles to the gneissic deformation" The compression of these veins and the gneissic deformation are thought to result from the doming-effect of a later granite.

Veins showing what appears to be typical ptygmatic folding have been repeatedly encountered by the writer in the great Sutherland granitic injection-complex[3]. A Sutherland vein showing ptygmatic

[1] Sander, B.,' Studienreisen im Grundgebirge Finlands,' *Verh. d.k.k. geol. Reichsanst.*, 1914, p. 82.

[2] Spurr, J. E., 'The Ore Magmas,' vol. i, 1923, pp. 164-70.

[3] Only part of this complex has been described. See J. Horne and E. Greenly, 'On Foliated Granites and their Relations to the Crystalline Schists in Eastern Sutherland,' *Quart. Journ. Geol. Soc.*, vol. lii, 1896, pp. 633-648; and H. H. Read, in 'The Geology of Golspie, Sutherland' (Explanation of Sheet 103), (*Mem. Geol. Surv. Scot.*), 1925, pp. 21-40; and in 'The Geology of Strath Oykell, etc.' (Explanation of Sheet 102), (*Mem. Geol. Surv. Scot.*), 1926, pp. 148-52. The Geological Survey Memoir on Sheets 108 (Altnaharra) and 109 (Kinbrace), now in preparation, deals with some 300 square miles of this complex.

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folding is figured in Fig. 1 and presents no essential differences from the Finnish ptygmatic veins; this figured vein is not an exceptional type. The lavish illustration of Sederholm's memoirs permits of detailed comparison between the Finnish and Scottish complexes; the similarity between the various structures of the two complexes has already been pointed out.[1] In the writer's opinion it is certain that veins showing what Sederholm calls ptygmatic folding are common in the Sutherland complex.

The Sutherland veins occur chiefly in rocks of the Moine Series and then in the siliceous and semipelitic granulites of that Series; more rarely typical ptygmatically folded veins are found in the hornblende-schists that represent basic igneous rocks of pre-metamorphism age. The Moine granulites show, in general, a marked banded structure by variation in the amount of biotite. With rare exceptions, the foliation agrees with this original sedimentary banding. The veins consist of quartz and felspar; their materials show no foliation, no directed structures, no cataclasis. The relations of these veins to the foliation of the Moine rocks can be seen from the series of sketches given in Fig. 2 and need not be detailed. Special points of these sketches will be emphasised in the following discussion.

Consideration of the Sutherland veins leads to the conclusion that none of the explanations of ptygmatic folding already summarised is applicable to them.

First may be taken the dynamometamorphic interpretation of Milch, Sander and Spurr. The Sutherland veins show no metamorphic phenomena; they belong to an epoch believed to be later, though, it is true, not much later, than the production of the Moine metamorphism. There is no agreement between the vein-folding and the host-folding, as can be seen by a glance at practically any of the sketches in Fig. 2. The dynamometamorphic interpretation implies that ptygmatic veins were once straight (or rather, plane). Many of the drawings of Fig. 2, such as A, B, E, G, K and M, show at once that the tortuous veins were never plane. Very commonly the Sutherland veins follow faithfully the contortion of the Moine sediments. It might be argued that such veins were folded with the sediments and were originally plane. Apart from the absence of metamorphic phenomena in the veins, the occurrence of vein-systems such as those of sketches E, K, M, N and Q of Fig. 2 shows the impossibility of such folding.

In the second place, the production of ptygmatically folded veins by endogenous secretion during ultrametamorphism, as favoured by Holmquist, is clearly not operative in the Sutherland examples. Quartz secretions and quartzo-felspathic pegmatite-like secretions are well known in many Highland pelitic rock-groups, but are scarce or absent in the normal siliceous and semipelitic granulites of the Moine Series of Sutherlandshire. Further, the clearly intrusive igneous nature of the veins, and their definite association with great

[1] Read, H. H., *loc. cit.*, 1925, p. 33.

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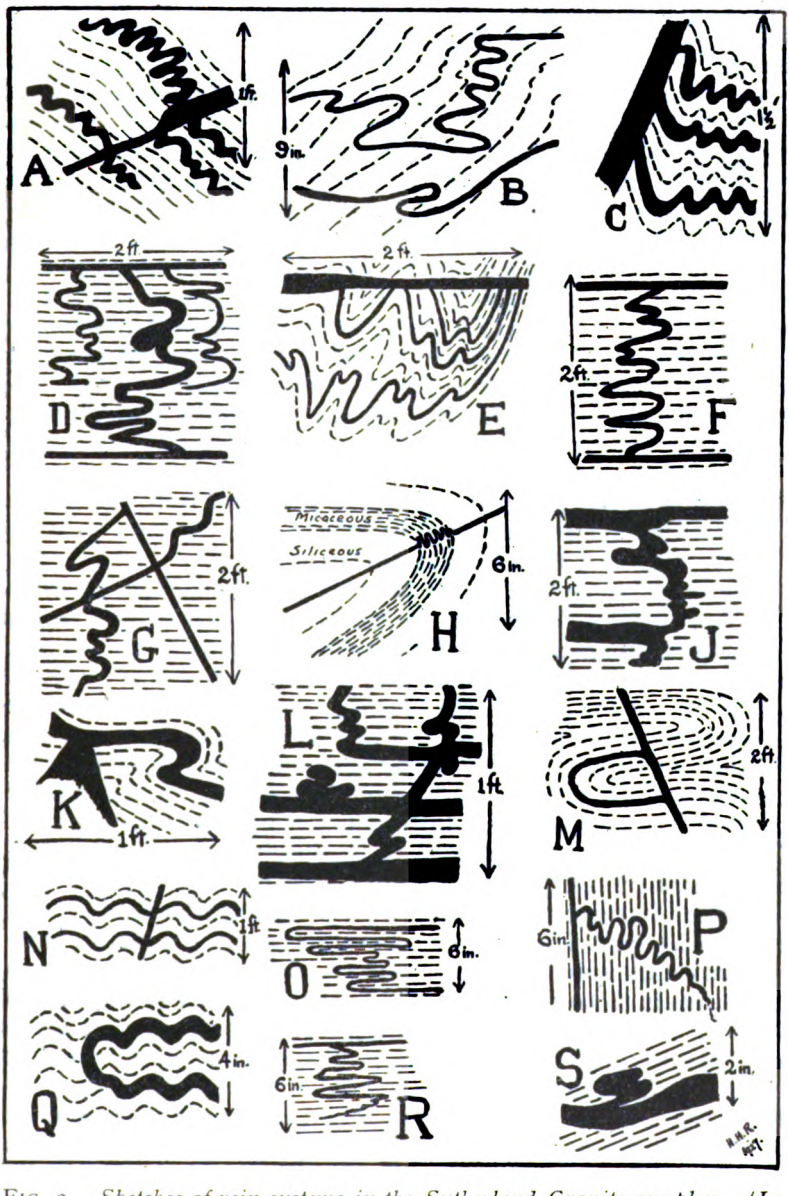

FIG. 2. —*Sketches of vein-systems in the Sutherland Granite-complex.* (*In each sketch, all veins are of the same age.*)

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igneous bodies of unquestionable origin, show that they were not produced by secretion during regional metamorphism. Again, the Moine sediments in which these veins occur differ in few respects from similar sediments outside the complex; their grain-size is slightly larger and they are sometimes tougher and less flaggy; there is, however, no question of their having undergone any ultra-metamorphic change or having attained any degree of plasticity.

Finally, the application of Sederholm's views on ptygmatic folding to the Sutherland veins is difficult from several aspects. Sederholm's supposition that these veins were originally straight (plane) cannot hold for veins such as those of sketches A, B, E, G, K and M of Fig. 2. It is difficult to believe that liquid veins during folding could preserve a uniform breadth, or could be folded on a plan different from that of the host-folding or, in fact, could exist as continuous liquid veins at all. The plane folding of the Moine sediments in which tortuous veins occur differs in no respects from that of similar rocks quite outside the injection-complex; there is no evidence that the veined Moine sediments were ever in a softened or semi-molten condition.

In the writer's opinion, it is evident

(1) that the tortuous veins of Sutherland were never plane.
(2) that their forms are original,
(3) and that they are non-metamorphic.

The term 'folded' suggests the idea of 'original straightness' of the thing folded. Thus, certain tortuous veins having been described as ptygmatically folded, they should originally have been in general straight. In this measure, Sederholm's term 'ptygmatic folding' is not for general use, even for exactly similar structures; its employment denotes that the user is prepared to demonstrate that the structures under discussion are secondary. It is the writer's opinion, derived from a fairly complete survey of the available literature, that in no case has the original planeness of 'ptygmatically folded' veins been demonstrated. The original tortuosity of similar veins in Sutherland is a matter of observation.

Certain features of the occurrence of the Sutherland veins are worthy of emphasis. The dominant factor in the production of tortuosity (not reproducing that of the original folding of the country-rock) appears to be the resistance of the rock concerned to plane-fissuring. Time and again, veins have been observed that are perfectly plane '*lits*' when parallel to the bedding or foliation, but show marked tortuosity when they leave these controlling guides, (see sketches D, F, J, L, O, P and R of Fig. 2). The same control is evident in the vein shown in Sketch H; this vein is plane when traversing the plane-fissuring siliceous granulites but is tortuous in the more resistant micaceous band. The tortuous side-veins shown in Sketch A likewise traverse micaceous bands in the granulite. The absence of easily opened plane channels for the injected material thus affects the form of the veins. Injection into a structureless country-rock not readily giving plane fissures should, on this

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interpretation, be especially marked by the occurrence of tortuous 'ptygmatically folded' veins. In the immediate neighbourhood of an injection-complex the country-rock undergoes injection-metamorphism which, whether it be of thermal, metasomatic or mixed type, produces a partial loss of directed structures and the formation of rocks more massive than those outside the complex. Thus, in Sutherland, 'ptygmatically folded' veins are common in the 'hardened' rocks of the injection-complex proper whilst, outside this, when they occur they do so more often in the relatively massive hornblende-schists than in the associated plane-fissuring Moine sediments.

An examination of the published work of J. J. Sederholm shows, in the writer's opinion, that the typical ptygmatic folding of the Finnish complexes occurs in veins traversing relatively structureless rocks not readily giving plane fissures. Thus, for example, Sederholm remarks of his type ptygmatite locality that "the surrounding schist shows a hälleflint-like appearance and is apparently more massive than the rest of the schist"[1]; again, in the Helsingfors region, the rock containing the veins is often a hornblende-gneiss or metabasite[2]. Moreover, veins that are straight in 'meta-andesite, that shows a better preserved primary texture, occasionally exhibit, when they reach hälleflint-like rock, the peculiar kind of folding which the author has called ptygmatic'[3]. Sederholm concludes that the hälleflint-like character of the associated country-rock is the expression of its partial plasticity during the ptygmatic folding. The present writer would suggest that the hälleflint-like character of the country-rock, resulting from injection-metamorphism, is as in the Sutherland cases the prime cause of the original tortuous form of the injections.

In conclusion, the following points emerge from the examination of the Sutherland tortuous veins.

(1) Sutherland veins, resembling the ptygmatic veins of Sederholm, are considered to have their original form; they were never plane.

(2) They are connected neither with ultrametamorphic nor dynamometamorphic phenomena; they are true igneous injections, showing no metamorphic characters.

(3) Their tortuous form, it is suggested, results from the resistance to plane fissuring of the country-rock, a resistance arising from the mineralogical and structural habit of the rock, the latter being in many cases the effect of injection-metamorphism.

(4) The term 'ptygmatic folding' denotes that the user believes that veins showing this folding were originally straight; the term should be limited to such cases.

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[1] *Neues Jahrb.*, B.Bd. 36, 1913, p. 495.
[2] *Ibid.*, p. 502.
[3] *Bull. Com. Géol. Finlande*, No. 58, 1923, p. 85.

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XI.—THE ADISHAM BORING, KENT

By J. PRINGLE.

During the passage of the memoir on 'The Concealed Mesozoic Rocks in Kent,' (*Mem. Geol. Surv.*, 1923) through the press, a boring was in progress at Adisham, and excepting a few references to it we were unable to give in that volume details of the rocks encountered in the exploration. Through the kindness of Mr. E. O. Forster Brown, permission has now been granted to publish an account of the Mesozoic rocks and those older than the Coal Measures.

Borehole about 90 *yds. N. of church at Adisham*, 1922-3. *About* 133 *ft. above Ordnance Datum*

		Thickness. Ft.	In.	Depth. Ft.	In.
	Soil	1	0	1	0
Chalk 777 ft.	White Chalk with flints. No cores ...	517	0	518	0
	Chalk. No cores	82	0	600	0
	Soft white chalk, core samples from various depths between 600 ft. and 659 ft.	59	0	659	0
	Greyish-white chalk with *Schloenbachia varians*, *Nautilus elegans* and *Inoceramus crippsi*. At base a line of greenish-black phosphatic nodules... ...	86	0	745	0
	Grey marly chalk with a band of dark silty clay between 759 ft. and 762 ft.	33	0	778	0
Gault	Dark clays; no cores	168	0	946	0
Sandgate Beds 8 ft. 5 in.	Soft brown glauconitic sand, hard band at top	6	5	952	5
	Dark grey clayey sand	2	0	954	5
Atherfield Clay 10 ft. 4 in.	Firm marly clay of a rich chocolate brown colour. From 961 ft. downwards the clay contains numerous small polished phosphatic grains and rounded fragments of bone. Clay rests on an irregular surface of a Wealden limestone	10	4	964	9
Wealden 30 ft. 3 in.	Thin bluish-grey limestone with Cyprids. The upper surface shows worm-burrows infilled by the basal bed of Atherfield Clay	—	3	965	0
	Slaty-grey clay with Cyprids and fish fragments	—	6	965	6
	Bluish-black and grey silty clays with a thin grey earthy limestone at 967 ft. Cyprids and fish remains abundant...	28	6	994	0
	Hard pale grey fine grained sandstone with many fragments of lignite, about	1	0	995	0

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		Thickness. Ft.	In.	Depth. Ft.	In.
Oxford Clay 82 ft.	Grey marly clay with a few hard marly bands. *Quenstedtoceras* fragments seen at 1,030 ft.; cores imperfect ...	44	0	1,039	0
	Greyish-white limestone with *Rhynchonella sp.*	1	0	1,040	0
	Brownish marly clay, becoming sandy at base. *Astarte spp.* and *Cucullaea* cf. *subtetragona* (Mor.)	36	0	1,076	0
	Brownish sandy shelly marl crowded with crushed shells of *Pseudomonotis sp. nov.*	1	0	1,077	0
Kellaways Rock 33 ft. 4 in.	Brownish grey calcareous sandrock with many small bits of bright polished ironshot	2	3	1,079	3
	Soft brown sandrock with many grains of polished ironshot; poor cores; 1½ ft. of core representing	6	8	1,085	11
	Greenish-brown somewhat soft ironshot sandrock; poor cores, 2 ft. of core representing	12	8	1,098	7
	No core	6	7	1,105	2
	Greenish-brown sandy marl with bright grains of polished ironshot plentifully scattered throughout matrix. *Gryphaea*, etc., at base, core imperfect...	5	2	1,110	4
Cornbrash 19 ft. 8 in.	Grey Clay		8	1,111	0
	Greyish-white finely oolitic limestone, becoming marly below	9	0	1,120	0
	Dingy grey oolitic shelly limestone; casts of the shells filled with coarsely crystalline calcite, limestone mixed with dark marl at base	4	0	1,124	0
	Hard cream coloured limestone sprinkled with small brown grains of ironshot...	5	0	1,129	0
	Dark grey muddy nodular limestone with dull brown specks of ironshot. *Rhynchonella major* Desl. and *Terebratula sp.*	1	0	1,130	0
Forest Marble 8½ ft.	Greenish black marly clay with a 6-inch band of greenish clay at 1,133 ft. 5 inches	4	0	1,134	0
	Blotchy grey marly clay with many shells and plant fragments in lower part	2	0	1,136	0
	Creamy oolitic limestone, irregularly indurated, and mixed with greenish clay	—	6	1,136	6
	Dark marly shelly clay with *Epithyris marmorea* (S. Buckman)	2	0	1,138	6
Great Oolite Series 61½ ft.	Hard bluish-grey oolitic limestone with a few thin marly bands	60	6	1,199	0
	Black shelly clay passing down into a dark sandy clay with pebbles of limestone. Bed indurated at base. *Homomya gibbosa* (J. Sow.) and *Mytilus furcatus* Mor. and Lyc. ...	1	0	1,200	0

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			Thickness. Ft.	In.	Depth. Ft.	In.
		Unconformity.				
Lias 12½ ft.	Upper 4 ft.	Dingy grey marly clay with *Dactylioceras spp.* and small crushed *Rhynchonellae*	4	0	1,204	0
	Middle 5 ft.	Hard grey limestone, somewhat muddy in places; *Pecten inaequivalvis* J. Sow., etc.	4	0	1,208	0
		Dark sandy clay with *Belemnites sp.*	1	0	1,209	0
	Lower 3½ ft.	Smooth silty black clay with a layer of pebbles at base. *Nuculana sp.* (B) etc.,; resting on Coal Measures	3	6	1,212	6
Coal Measures			2,025	3	3,237	9
Carboniferous Limestone			27	0	3,264	9

Generally, the section of Mesozoic rocks is the same as that provided by the Fredville boring and the Snowdown shafts, excepting that the Lower Corallian beds are cut out at Adisham, where the Wealden Series rests on a horizon high in the Oxford Clay. The unconformable relationship of the Cretaceous rocks to the underlying Jurassic formation is thus clearly demonstrated.

The presence of the three divisions of the Lias in thin development, however, was to some extent unexpected, and it is now evident that the boundary of the formation must lie on the north-eastern side of the railway between Snowdown and Adisham. In the excellent cores it was possible to assign a separate thickness for each subdivision.

Rocks of Lower Carboniferous age were entered at the depth of nearly 3,238 ft. They consist of dark grey bituminous and porcellaneous limestones; and although no fossils were found, the lithological characters of the beds suggest that the limestones are probably the same as those of S_1—S_2 age found at Elham. In the Adisham boring the upper surface of the limestone is exceedingly irregular, and the hollows are filled with clays of the overlying Coal Measures.

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XII.—ON FOSSILS FROM THE COAL MEASURES OF KENT

By J. PRINGLE and R. CROOKALL, PH.D.

In the *Summary of Progress* for 1916 the details of the Coal Measures passed through in three deep borings in Kent were given in an Appendix.[1] A small number of fossils, identified at the time of collecting, were included in the description of the rocks, and it was stated that, as the fossils were still under investigation, publication of the full results must be deferred. We therefore propose to give these details in the following pages. Of the plants collected, the majority were named by the late Dr. R. Kidston,[2] but all of them have since been revised by one of us, whilst the other author, the collector of all the material, is responsible for the identification of the molluscan and other remains.

No marine shells were noted in any of the borings. A large fragment of a species of *Eurypterus* was found at Elham, and, although it cannot be specifically determined, it is worthy of placing on record on account of the rarity of this genus in the British Coal Measures. The plants collected form a representative suite, and include a number of rare and interesting forms. Among them is a single piece of petrified wood which is identified as *Dadoxylon sp.* In this connexion, it is of interest to note that similar petrified plant-remains are known both from the Bristol and Somerset and the South Wales Coalfields.[3]

Elham Borehole

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris lonchitica (*Schloth*).	2,254
Lonchopteris rugosa *Brongt.*	1,720
Mariopteris nervosa *Brongt.*	1,975
Neuropteris gigantea *Sternb.*	1,845, 2,030
,, heterophylla *Brongt.*	2,030
,, microphylla *Brongt.*	2,032
,, tenuifolia (*Schloth.*)	2,118, 2,122
,, sp.	1,975, 2,030, 2,176, 2,254
Sphenopteris sp.	2,162
Lycopodiales	
Lepidodendron sp.	1,706
Lepidostrobus anthemis (*König*)	1,706, 1,709
Sigillaria laevigata *Brongt.*	1,726
,, sp.	1,634
Stigmaria ficoides (*Sternb.*)	1,744, 2,044, 2,196
,, sp.	2,283

[1] Pringle, J., 'On deep borings for Coal and Ironstone at Bere Farm, Elham, and Folkestone, Kent,' 'Summary of Progress' for 1916 (*Mem. Geol. Surv.*), 1917, pp. 34-40.

[2] A preliminary list of these records was printed in the 'Summary of Progress' for 1918 (*Mem. Geol. Surv.*), Appendix 2, p. 46.

[3] Crookall, R., 'On *Sutcliffia lilliei* n. sp.,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 161-167.

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	Depth in ft.
Equisetales	
Asterophyllites equisetiformis (*Schloth.*)	1,720
Calamites suckowi *Brongt.* 1,944,	1,946, 2,074
,, undulatus (*Sternb.*)	1,820
Calamitic cone	2,190
Sphenophyllales	
Sphenophyllum sp.	2,160
Cordaitales	
Cordaites principalis (*Germar*)	1,720
Semina incertae sedis	
Carpolithes membranaceus *Göpp.*	1,720
ARTHROPODA	
Eurypterus sp.	2,251

Bere Farm Borehole

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris davreuxi (*Brongt.*) ... 1,880-1,886,	2,055-2,056
Aphlebia sp.	1,994
Asterotheca miltoni (*Artis*) 1,880-1,886,	2,684-2,690
,, *cf.* miltoni (*Artis*) 1,880-1,886,	1,994
Cyclopteris sp.	2,944
Linopteris münsteri (*Eichw.*)	2,944
Mariopteris nervosa *Brongt.*	2,684-2,690
,, sp.	2,684-2,690
Neuropteris macrophylla *Brongt.*	1,880-1,886
,, *cf.* macrophylla *Brongt.* 1,880-1,886,	1,970
,, microphylla *Brongt.*	2,550, 2,911
,, missouriensis *Lesqx.*	2,684-2,690
,, obliqua (*Brongt.*)	2,630-2,635
,, ovata *Hoffm.* 1,880-1,886, 2,550,	2,684-2,690
,, *cf.* ovata *Hoffm.*	1,880-1,886
,, rarinervis *Bunb.* ... 1,975, 2,348, 2,550, 2,630-2,635,	2,911
,, *cf.* rarinervis *Bunb.* ... 1,880-1,886, 1,975, 2,684-2,690,	2,924, 2,944
,, scheuchzeri *Hoffm.* ... 1,880-1,886, 1,970, 2,055-2,056,	2,630-2,635, 2,684-2,690, 2,911, 2,924
,, *cf.* scheuchzeri *Hoffm.*	1,970
,, sp. 2,630-2,635, 2,684-2,690,	2,911, 2,944
Odontopteris lindleyana *Sternb.*	2,944
,, *cf.* lindleyana *Sternb.* ... 1,880-1,886,	2,005-2,008
Pecopteris *cf.* pennaeformis *Brongt.*	2,684-2,690
,, *cf.* richardsoni *D. White*	2,684-2,690
,, (Cyatheites sp.) 2,550,	2,684-2,690
,, sp.	1,880-1,886
Ptychocarpus *cf.* unitus (*Brongt.*)	1,880-1,886
Sphenopteris *cf.* neuropteroides *Boulay*	1,994
Lycopodiales	
Sigillaria tessellata *Brongt.*	2,684-2,690
Stigmaria ficoides (*Sternb.*)	1,864, 2,754
Equisetales	
Annularia sphenophylloides (*Zenker*) ... 1,880-1,886, 2,684-2,690,	2,944
,, stellata (*Schloth.*)	1,880-1,886
Calamites suckowi *Brongt.* 1,880-1,886,	1,926, 2,550
,, *cf.* suckowi *Brongt.*	1,990
,, sp. 1,920,	2,684-2,690
Palaeostachya elongata *Presl*	2,005-2,008

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	Depth in ft.
Sphenophyllales	
Sphenophyllum emarginatum *Brongt.* ...	1,880-1,886, 2,005-2,008
,, sp.	2,684-2,690
Cordaitales	
Cordaites sp.	1,880-1,886, 2,085
Dorycordaites palmaeformis (*Göpp.*)	2,911
Antholithus sp.	1,880-1,886
Cordaianthus sp.	2,081
Semina incertae sedis	
Samaropsis arberi *Kidst.* [MS.] [1]	1,920
Cf. Trigonocarpus sp.	1,880-1,886

Boring at Tower Brickworks, Folkestone

PLANTS

	Depth in ft.
Pteridospermeae and *Filicales*	
Alethopteris aquilina (*Schloth.*)	1,723-1,725, 2,072
,, serli (*Brongt.*)	1,690, 1,715, 1,723-1,725
Asterotheca miltoni (*Artis*) ...	1,723-1,725, 1,980, 2,950-2,955, 3,095-3,097
Cf. Asterotheca miltoni (*Artis*)	2,990-2,993
Cf. Asterotheca oreopteridia (*Schloth.*)	1,760
Dactylotheca plumosa (*Artis*)	1,620
,, ,, *forma* dentata *Bgt. pro sp.*	3,095-3,097
Cf. Eremopteris artemisaefolia (*Sternb.*)...	1,590, 1,636 1,996, 2,914
Eupecopteris bucklandi (*Brongt.*)	2,950-2,955
Mariopteris nervosa (*Brongt.*)	1,647-1,649, 1,784-1,787
,, sp.	1,647-1,649
Neuropteris *cf.* callosa *Lesqx.*	2,780
,, fimbriata *Lesqx.*	1,792-1,795, 1,846
,, flexuosa *Sternb.*	1,647-1,649, 1,837-1,840, 1,846
,, flexuosa *Sternb. var.* rotundifolia (*Bgt.*) ...	1,647-1,649
,, gigantea *Sternb.*	1,846
,, *cf.* grangeri *Brongt.*	2,760
,, ovata *Hoffm.*	1,792-1,795
,, rarinervis *Bunb.* ...	1,557, 1690, 1,708-1,710, 1,723-1,725, 1,780, 1792-1,795, 1,873, 2,242, 2,790, 2,765
,, scheuchzeri *Hoffm.* ...	1,548-1,552, 1,647-1,649, 1,780, 1,784-1,787, 1,792-1,795, 1,846, 1,980, 2,038, 2,044, 2,635-2,640, 2,990-2,993, 3,290, 3,298.
,, *cf.* scheuchzeri *Hoffm.*	1,647-1,649
,, sp. ...	1,647-1,649, 1,837-1,840, 1,846, 2,760, 2,765, 2,806. 2,950-2,955, 2,990-2,993, 3,286, 3,295
Odontopteris *cf.* lindleyana *Sternb.*	1,760
Pecopteris (Cyatheites sp.) ...	1,548-1,552, 1,590, 1,764, 2,044, 3,290
,, sp.	1,678, 2,990-2,993
Renaultia chaerophylloides (*Brongt.*)	1,768, 1,980
Urnatopteris herbacea (*Boulay*)	1,768
Sphenopteris striata *Gothan*	1,780, 2,072
,, sp.	1,585, 1,792-1,795
Lycopodiales	
Lepidodendron fusiforme *Corda*	1,846
,, rimosum *Sternb.*	1,846
,, sp.	1,784-1,787, 2,030, 2,038

[1] Awaiting publication.

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	Depth in ft.
Lepidophyllum lanceolatum *L. & H.*	1,980
„ majus *Brongt.*	1,792-1,795
„ sp.	1,780
Lepidostrobus anthemis (*König*)	1,780, 3,095-3,097
„ sp.	1,980
Sigillaria sp.	1,487, 2,038
Sigillariophyllum sp.	2,038, 2,635-2,640, 3,095-3,097
Stigmaria ficoides (*Sternb.*)	1,578
„ sp.	3,400
Equisetales	
Annularia galioides (*L. & H.*)	1,747
„ sphenophylloides (*Zenker*)	1,647-1,649, 1,708-1,710, 1,715, 1,723-1,725, 1,873, 1,969, 1,980, 2,826, 2,950-2,955, 3,095-3,097
„ stellata (*Schloth.*)	1,708-1,710, 1,980, 2,284, 2,635-2,640
„ *cf.* stellata (*Schloth.*)	1,780, 2,284
Asterophyllites longifolius (*Sternb.*)	1,660
Calamites suckowi *Brongt.*	1,548-1,552, 1,557, 1,585, 1,620, 1,647-1,649
„ sp.	1,535-1,538, 1,548-1,552, 1,620, 1,784-1,787, 1,816, 2,483, 2,484, 2,890
Stachannularia tuberculata (*Sternb.*)	1,792-1,795
Calamitic cone	1,557, 1,747
Sphenophyllales	
Sphenophyllum emarginatum *Brongt.*	1,647-1,649, 1,980, 2,044
„ majus *Bronn*	1,780
„ sp.	1,590, 1,647-1,649, 1,980
Cordaitales	
Cordaites borassifolius (*Sternb.*)	1,708-1,710, 1,950
„ sp.	1,490, 1,768
Dorycordaites palmaeformis (*Göppert*)	1,748, 1,980
Dadoxylon sp.	2,591
Semina incertae sedis	
Carpolithes membranaceus *Göppert*	1,723-1,725
Holcospermum mammillatum *Lesqx.*	1,647-1,649
Samaropsis arberi *Kidst.*	2,242
„ crassa (*Lesqx.*)	2,242
„ fluitans *Arber* (non Dawson)	1,764
„ reniformis (*Geinitz*)	1,723-1,725
Mollusca, etc.	
Anthracomya phillipsi (*Will.*)	2,019
„ phillipsi ? (*Will.*)	1,886, 2,473
„ tenuis *Davies and Trueman*	1,987, 2,019
„ sp.	2,284
Ostracods	2,019

In 1915, Dr. H. Bolton[1] divided the Coal Measures of Kent into an Upper and Lower Series, and, on lithological and faunal evidence regarded ' The Kent Upper Series as Pennant-Farrington in age, when compared with the Measures of Somerset.' He added, however, that the beds ' are equally Westphalian when compared with the Coal Measures of Belgium and Northern France,' thus, presumably, suggesting a Middle Coal Measure horizon for his Kent Upper Series. Bolton also concluded[2] that ' The Lower Series of

[1] Bolton, H., ' The Fauna and Stratigraphy of the Kent Coalfield,' *Trans. Inst. Mining Eng.*, vol. xlix, 1915, pp. 643-702.
[2] *Op. cit.*, p. 693.

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sandstones and binds have a fauna which, so far as is yet known, is comparable to that of the Vobster, Ashton, and Bedminster Series of the Bristol and Somerset Coalfield,' and he[1] described the beds as 'typically of Lower Coal Measure age.' On floral evidence, Arber,[2] however, referred the upper part of Bolton's Upper Series to the Transition Coal Measures (=the Staffordian Series), and the lower portion of the Kent Coal Measures to the Middle Coal Measures (= the Yorkian Series). The apparent discrepancy between these two results was removed in the discussion on Dr. Bolton's paper, when Wheelton Hind[3] observed that 'the base of the Kentish Coal Measures, . . . did not pass much, if at all, below the horizon of the Knowles Coal of North Staffordshire. There was consequently no contradiction between the palaeobotanical and the faunal evidence.' He was absolutely in agreement with Dr. Arber's views, but on totally different grounds.

The plant and animal remains found in the borings at Elham, Bere Farm and Folkestone, as set forth in the above tables, lend support to the views of Arber and Kidston. Indeed, the presence of strata of high Staffordian age is clearly shown by the fauna of the upper part of the Measures at Folkestone, in which occur abundant examples of *Anthracomya phillipsi* (Will.) in association with *A. tenuis* Davies and Trueman, thus showing that the strata must fall in the lower portion of the Zone of *Anthracomya tenuis* of these authors.[4] The floral evidence is equally convincing. The top 500 feet of the Coal Measures contain a flora which is a mixture of Radstockian and Yorkian plants, and the beds thus belong to the Staffordian Series (Transition Coal Measures). The most frequent of the Radstockian forms are *Neuropteris ovata, N. scheuchzeri, N. rarinervis, N. flexuosa, N. fimbriata,* and *Alethopteris serli,* while of less common occurrence are *Alethopteris aquilina, Dactylotheca plumosa, Asterotheca oreopteridia, Annularia sphenophylloides, A. stellata,* and *Sphenophyllum emarginatum. Urnatopteris herbacea* is known only from the Staffordian Series. With the Radstockian species are found several Yorkian plants, but these are of rare occurrence; they include *Eremopteris artemisaefolia, Renaultia chaerophylloides, Mariopteris nervosa, Sphenopteris striata,* and *Asterophyllites longifolius.* Although the flora is a mixed one, the Radstockian elements largely preponderate, and it is thus evident that the strata belong high up in the Staffordian Series, and can be referred with certainty to the Newcastle-under-Lyme Group.

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[1] *Op. cit.*, p. 668.

[2] Arber, E. A. N., 'On the Fossil Plants of the Waldershare and Fredville Series of the Kent Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, pp. 21-39; 'On the Fossil Flora of the Kent Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxx, 1914, pp. 54-81; and 'Studies of the Geology of the Kent Coalfield—Pt. I: The Coal-Measure records of four Borings,' *Trans. Inst. Mining Eng.*, vol. l, 1916, pt. 2, pp. 351-372.

[3] Discussion of Mr. Herbert Bolton's paper on 'The Fauna and Stratigraphy of the Kent Coalfield,' *Trans. Inst. Mining Eng.*, vol. l, 1916, pt. 2, pp. 294-319.

[4] Trueman, A. E., and J. H. Davies, 'A revision of the non-marine Lamellibranchs of the Coal Measures,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, pp. 210-259.

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Recent work by one of the present authors [1] has shown that a typical Yorkian flora is present in the so-called Millstone Grit of the Bristol Coalfield, while there is no indication of a Lanarkian flora, so that the plant divisions represented in the two coalfields may now be compared as follows:

	Kent Coalfield	Bristol Coalfield
Radstockian Series	absent	present
Staffordian Series	present	present
Yorkian Series	present	present
Lanarkian Series	absent	absent

[1] Crookall, R., 'On the Fossil Flora of the Bristol and Somerset Coalfield,' *Geol. Mag.*, vol. lxii, 1925, pp. 403-404.

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XIII.—PALAEOZOIC SPECIES OF *VETACAPSULA* AND *PALAEOXYRIS*

By R. CROOKALL, PH.D.

Plates I, II.

During the year I received from Mr. W. D. Ware of Ystradgynlais, Swansea, several fossils which clearly belonged to undescribed species of the rare and problematical genera *Vetacapsula* and *Palaeoxyris*. In the course of preparing descriptions of these specimens it became evident that the definition of certain existing species of the genera was not entirely satisfactory, and that certain features (e.g. the angle formed by the ribs in *Palaeoxyris*) have never received accurate description. A careful comparison of all available specimens [1] also brought to light a much greater variation in the members of individual species than has previously been described. The observations made having necessitated a re-statement of the diagnostic characters, a brief critical revision of the two genera has been undertaken. Previous records of the fossils have been classified and a number of new records made. The present account is concerned with morphological considerations only, but it is hoped, at a later date, to deal with the nature and affinities of the organisms.

GENERAL DESCRIPTION

Vetacapsula and *Palaeoxyris* are fusiform sacs of varying proportions and dimensions. While certain authors [2] have regarded the fossils as composed of a number of leaf-like valves united by their margins, Pruvost [3] and others consider them to consist of two valves only, each bearing several longitudinal ribs. Nathorst,[4] however, suggested (for *Spirangium=Palaeoxyris*) a construction built up of tubes, after the manner of the 'fruits' (oogonia) of *Chara*. I postpone, at this stage, a discussion of the two latter

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[1] The specimens examined include those in the following collections: The Museum of Practical Geology and Geological Survey Collections, London; Geological Survey (Scottish Office); British Museum (Natural History); Manchester Museum; Bristol Museum; Barnsley Naturalist and Scientific Society; Geological Survey of Sweden; the Riksmuseets Paleobotaniska Avdelning, Stockholm. Specimens have also been examined in the private collections of Mr. H. W. Hughes of Dudley and Mr. W. R. Barker of Barnsley, while a number of workers have sent me examples which they had collected. My thanks are due to the curators and owners of the various collections for kind assistance in this matter.

[2] See Kidston, R., 1886, 'On the Species of the Genus *Palaeoxyris*, Brongniart, occurring in British Carboniferous Rocks,' *Proc. Roy. Phys. Soc. Edinb.*, vol. ix, p. 59.

[3] Pruvost, P., 1919, 'La faune continentale du terrain houiller du nord de la France,' *Mém. Carte Géol. Dét. de la France*, pp. 445-446.

[4] Nathorst, A. G., 'Om *Spirangium* och dess förekomst', I, Skånes Kolförande Bildningar, Sveriges Geol. Undersökning, Ser. C, No. 36, 1879, pp. 1-13, pl. vi, vii. (I am most obliged to Dr. R. Florin, of the Riksmuseets, Paleobotaniska Avdelning, Stockholm, for kindly providing me with a resumé of Nathorst's paper.)

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views, Pruvost's conception being sufficient for descriptive purposes. The ribs borne on the valves are more or less raised, and vary in number in different species, the areas between them being termed 'bands' or 'segments.'[1] In *Palaeoxyris* the valves are twisted longitudinally, so that the ribs appear as spiral lines traversing them at various angles, and, in examples which have suffered compression during fossilisation, by their intersection, dividing the segments into rhomboidal areas. These rhomboids were originally described by Brongniart [2] as representing adpressed imbricating scales, but were subsequently shown by Schimper [3] to be merely due to compression of the organism in fossilisation. In *Vetacapsula*, on the other hand, the valves typically remain erect and the ribs pursue a longitudinal course roughly parallel to the longer axis or, more correctly, to the contour of the fossil. Apparent exceptions to this construction are seen in *Vetacapsula johnsoni* (Kidston) and *V. czernyshevi* Chabacov[4], where locally a slight spiral twist is observable in the ribbing.

In *Vetacapsula* and *Palaeoxyris* the body tapers at one extremity into a 'beak' and at the other into a 'pedicle,' the former, when preserved intact, having a definite sharply pointed termination, but the latter appearing to have been of indefinite length. At or just below the centre of the fossil is an enlarged, deformed, or crumpled region which is so constantly present in the organisms as to undoubtedly represent the original site of an essential organic structure.

The Significance of Surface Markings

(*a.*) Direction

In 1886 Kidston [5] noted the presence of 'very fine oblique lines' on the segments of a specimen of *P. prendeli* from Coseley, and an example of that species (No. V.1173) preserved in the British Museum bears similar oblique lines.

On the other hand, fine lines parallel to the ribbing may be observed on the beak of a specimen of *P. prendeli* (No. L.8672) preserved in the Manchester Museum. In 1870 the latter type of marking had been noted by Lesquereux [6] as occurring on a specimen of *P. helicteroides*, and, in 1911 Mr. J. W. Jackson [7] called attention to specimens of *P. helicteroides* from Lancashire, some of the bands of which exhibited, both on the body and on the beak, a striation parallel to the ribbing: this he thought

[1] It should be noted that the terms 'valves', 'ribs', 'bands' and 'segments' have often been very loosely used by certain authors.

[2] Brongniart, A., 1828, 'Essai d'une flore du grès bigarré,' *Ann. des Sci. nat., Ie Ser.*, vol. xv, p. 456.

[3] Schimper, W. Ph., 1869-1874, 'Traité d. paléont. végét.', vol. ii, p. 515.

[4] Chabacov, A. W., 1927, 'Sur une découverte des oeufs d'élasmobranches *Palaeoxyris* et *Vetacapsula* dans les dépôts carbonifères de la Russie,' *Bull. du Comité Géol. Léningrad*, vol. xlvi, No. 1, pp. 33-34, text-fig. 3, p. 33.

[5] Kidston, 1886, *op. cit.*, pl. I, f. 5 a, pp. 62-63.

[6] Lesquereux, L., 1870, *Geol. Surv. of Illinois*, vol. iv, pp. 464-465, pl. xxvii, f. 10, 10b (as *P. prendeli*).

[7] Jackson, J. W., 1911, 'Remarks on some *Palaeoxyris* from the Middle Coal Measures of Lancashire,' *Lancashire Naturalist* (Jan., 1911), p. 328.

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'to represent the actual impression of the outer surface of the organism,' comparing it with the condition found on the egg-capsules of the Port Jackson Shark and other fish. I have examined all available specimens of *P. helicteroides* and the presence of such ornamentation is not uncommon. The collection of the British Museum contains three specimens so marked, while that of the Museum of Practical Geology includes no less than 18. Although the occurrence of similar lines in the genus *Vetacapsula* has not hitherto been recorded, they are found in a few instances, e.g., on one or two examples of *V. cooperi*. Striae running parallel to the ribbing have been noted in two species of *Fayolia*, namely, *Fayolia sterzeliana*[1] and *F. crenulata*[2], while a specimen of *Fayolia sp.*[3] (No. R.C.253, Museum of Practical Geology), collected by Mr. Ware from the Ystradgynlais Colliery, South Wales, bears such markings on portions of the bands. In this genus also they have been compared with the fine lines on the egg-cases of the Port Jackson Shark[4].

In determining the significance of these markings on various specimens of *Palaeoxyris*, it should be remembered that in *P. helicteroides*, as in the much rarer *P. prendeli*, they may take various directions, although that parallel to the ribs is the most frequently found.

Very occasionally, in compressed specimens, the segments bear striae running parallel to each of the two intersecting systems of ribs[5], and tending to form minute faintly-marked rhomboids within the normal rhomboids. A fragment of *Palaeoxyris sp.*, sent me by Mr. J. Walton, and collected from above the Arley Mine (Yorkian Series) at Poynton Colliery, Cheshire, bears crossed striae of this kind, while two or three similar examples (on *P. helicteroides*) may be seen in the Museum of Practical Geology.[6]

Two specimens in the British Museum and ten in the Museum of Practical Geology show transverse striae; in some cases these are so fine as to be discernible only with the aid of a lens, but in others they are clearly visible to the naked eye. One such specimen is figured on Pl. II, fig. 9.

(*b.*) Distribution

Only in very rare instances are the striae distributed over the whole fossil, although the specimen may appear to be equally well preserved throughout. They are usually confined to a few segments only, and the rest of the fossil may be smooth,

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[1] Weiss, C. E., 1887, 'Ueber *Fayolia sterzeliana* n. sp.,' *Jahrb.d.k.preuss.geol.Landesanst.*, p. 94, pl. iv.

[2] Moysey, L., 1910, 'On *Palaeoxyris* and other Allied Fossils from the Derbyshire and Nottinghamshire Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxvi, p. 339.

[3] This specimen will be described later.

[4] Renault, B., and R. Zeiller, 1888, 'Sur l'attribution des genres *Fayolia* et *Palaeoxyris*,' *Compt. rend.*, vol. cvii, pp. 1022-1025.

[5] This phrase is, of course, purely descriptive; 'the two intersecting systems of ribs' as is pointed out above, are due to compression of the fusiform body which bore spiral ribbing.

[6] E.g. specimen J.P. 1009, from the Swansea Four-foot Seam at Cae-newydd Colliery, near Gowerton Station, South Wales. The feature is well-marked in this specimen.

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but in many cases there is a parallel striation on the beak and a transverse on certain segments of the body, while occasionally the reverse arrangement is found. Again, as in the example figured on Pl. II, fig. 9, transverse lines may be superimposed on parallel, each type nevertheless predominating on different parts of the organism; in this case the former are found on the beak and upper part of the body, and the latter on the lower half. It should also be noted that many otherwise excellently preserved specimens are quite devoid of markings of any kind. In view of these facts there can be little doubt that *the various types of ornamentation described do not represent original features in the specimens, but have been formed in the processes of mineralisation.*

Relationship between the Genera

First impressions suggest, and especially in considering the local spiral arrangement of the ribbing occasionally found in *V. johnsoni* and in the single known specimen of *V. czernyshevi*, that there is little or no real distinction between these two genera—that in *Vetacapsula* the ribs have not attained a definite spiral course through lack of maturity or some such accidental cause. The presence or absence of spiral ribbing, however, is by no means their only distinguishing character, and, though certain features are not constant, the two genera may be contrasted as in the following table:

	Vetacapsula	*Palaeoxyris*
Shape	usually broadly fusiform	more narrowly fusiform
Ribbing on body	not spiral, or only slightly (and locally) spiral	definitely spiral
Ribbing on pedicle	straight, and parallel to longer axis	twisted in spirals
No. of ribs	large	small
Width of segments	narrow	wide
Median ridge	present in most species	absent
Longitudinal symmetry	tendency to non-symmetry where central ridge is weak or absent	symmetrical

The distribution of the genera, both in time and space, is also significant. While *Palaeoxyris* is known not only from Britain and various continental countries, but also from North America, *Vetacapsula* has been recorded from Britain only, with the exception of the single record from the Russian Carboniferous. Again, while *Palaeoxyris* is recorded at a number of horizons, e.g., the Coal Measures, Trias, Rhaetic, Lower Lias and Wealden, *Vetacapsula*,

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so far as is known, is confined to the Coal Measures. *The two genera must thus be regarded as distinct, though they are obviously closely allied.*

SPECIES OF *VETACAPSULA*

Vetacapsula cooperi Mackie

Pl. I, figs. 1, 4.

The type specimen of *V. cooperi* is preserved in the British Museum (No. V.5419), and is here re-figured in Pl. I, fig. 1. Mackie's[1] brief description of the fossil is unsatisfactory, and his probable intention to amplify it in conjunction with Mr. C. W. Crocker never having materialised, Crocker cannot be cited as joint author of the species. In a later note, Mackie[2] indicated that the horizon and locality of his fossil were unknown.

The pedicle, of which 4 cm. are preserved, expands fairly gradually, without the formation of a definite 'shoulder', into a more or less ovate body. The latter is about 4.2 cm. in length and tapers into a beak of which only 1.6 cm. is preserved. At its widest point, just below the middle of the body, the fossil measures 3.9 cm., and it is here that the distorted area occurs. Running down both beak and body is a strong central ridge, but this is scarcely observable in the pedicle. As the result of the careful development of an apparently deformed specimen, Moysey[3] concluded that this ridge was due to the original presence of a flange which, on splitting the nodule containing the specimen, was torn off and left embedded in the matrix of the counterpart. There are about 25 longitudinal ribs across the widest part of the body, arranged fairly symmetrically on either side of the stronger median ridge. The ribs show no tendency to pursue a spiral course in any part of the fossil. The specimen is practically symmetrical in the longitudinal direction about the strong central line.

Vetacapsula cooperi is very variable in size, the average length and breadth being 3 cm. and 2.5 cm. respectively, but an example collected by Moysey and now in the Museum of Practical Geology (No. 47923) measures 4.8 cm. by 4.3 cm. (Pl. I, fig. 4), while an even larger, though less complete, specimen is exhibited in the British Museum (No. V.1395). The former example is in an excellent state of preservation, and the central ridge is clearly seen in beak, body and pedicle. The pedicle is 4 cm. long and 1 cm. broad, but the beak is incomplete, being perfectly preserved, however, in the counterpart (No. 47922) where it is seen to be 4 cm. long and sharply pointed. The ribs at the widest part of the body are about 1.5 mm. apart, showing no spiral arrangement at any point. In 1911, Mr. J. W. Jackson[4] described and figured a single specimen (No. L.9581, Manchester Museum), of this species from an unknown

[1] Mackie, J., 1867, 'Undescribed Vegetable Fossil,' *Geol. and Nat. Hist. Repertory*, vol. i, 1865-1867, pp. 79-80, text-fig. 12.

[2] *Op. cit.*, p. 216.

[3] Moysey, L., 1913, 'Some Further Notes on *Palaeoxyris* and other allied Fossils, with Special Reference to some New Features found in *Vetacapsula*,' *Rep. Brit. Assoc. Adv. Sci.*, 1913 (Birmingham), p. 492.

[4] Jackson, J. W., 1911, *op. cit.*, p. 330, pl. xi, f. i.

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locality. It is a typical example, but, by some curious mischance most, but not all, of the measurements given in the description are approximately doubled, as will be seen by referring to the figure (which is slightly less than natural size). I have examined this specimen, and the description should read, " At a distance of 4 cm., the pedicle, which is here about 12 mm. wide, expands into a globular body some 3.7 cm. in length and 3 cm. in breadth. The body then narrows to form a beak of 2.4 cm., or more, in length. The actual termination of the beak is not present owing to a breakage at this point."

Revised diagnosis of *Vetacapsula cooperi* Mackie

Body broadly fusiform, practically longitudinally symmetrical; usually longer than broad; from 2.5 to 4.9 cm. long and 2.5 to 4.6 cm. broad. Pedicle expands into body gradually, without forming a 'shoulder'. From 17 to 25 longitudinal ribs, 1.1 to 2.5 mm. apart, traverse the fossil, exhibiting no spiral tendency: there is a strong median ridge.

DISTRIBUTION

Horizon: ? Coal Measures.
Locality: unknown (C. W. Crocker—Mackie's type specimen).

Horizon: New Mine or White Ironstone (Yorkian Series).
Locality: near Dudley, Staffordshire (J. P. Capewell).

Horizon: Thick Coal (Yorkian Series).
Locality: Chilvers Coton Claypit, Warwickshire (R. D. Vernon).

Horizon: Furnace Coal (Yorkian Series).
Locality: Cossall Claypit, Nottinghamshire.

Horizon: Silkstone Coal (Yorkian Series).
Locality: Callow Colliery, Chesterfield (J. W. Jackson).

Horizon: between the Deep Hard and the Silkstone Coals (Yorkian Series).
Locality: Bonds Main Colliery, Temple Normanton, Derbyshire (L. Moysey).

Horizon: Arley Mine Coal (Yorkian Series).
Locality: Sparth Bottoms, Rochdale, Lancashire (W. H. Sutcliffe).

Vetacapsula moyseyi n.sp.

Pl. I, fig. 6.

In 1913, Moysey[1] observed that *Vetacapsula cooperi*, as described by him in 1910,[2] included two distinct species, and suggested that Mackie's type be designated 'forma β', and the divergent type 'forma α', but did not distinguish between them beyond indicating their characteristic shapes. I here remove Moysey's *V. cooperi* forma α from Mackie's species and redescribe it as *V. moyseyi* n.sp. The specimen figured on Pl. I, fig. 6 was collected by Moysey from the Kilburn Coal (Lanarkian Series[3]) at Loscoe Colliery, Derbyshire, and is now in the Museum of Practical Geology (No. 47925).

[1] Moysey, L., 1913, *op. cit.*, p. 492.
[2] ——, 1910, *op. cit.*, p. 335.
[3] 'Concealed Coalfield of Yorkshire and Nottinghamshire' (*Mem. Geol. Surv.*), 2nd ed., 1926, p. 10.

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The total length of the fossil is 5.6 cm. The margins of the pedicle, which measures 2.5 cm. long and 5.5 mm. broad, take a strong curve in passing into the body, a feature well described by Moysey.[1] 'The pedicle expands suddenly into the body, thus forming a characteristic rounded shoulder in the contour of the body at its lower third, and imparting to the body, in its present compressed state, a shape somewhat like that of a conventional heart inverted.' In *V. moyseyi* the body of the fossil is broader than long, this specimen measuring 2.7 cm. in width and 2.2 cm. in length, and the region of greatest width being situated farther down the body than in *V. cooperi*. The margins which converge to form the beak are also noticeably less curved than in that species. About 16 ribs occupy the broadest portion of the body, each adjacent pair being separated by 2 mm. Body and beak are practically symmetrical about a strong median longitudinal ridge, the pedicle, however, taking a slightly oblique course. The beak is incomplete, but it probably terminated in a point.

As in *V. cooperi*, the specimens vary considerably in size. Moysey described his specimen (from Newthorpe Claypit, Eastwood), as 5.6 cm. broad by 4.7 cm. long, while in the Kidston Collection (No. 6994) is the plaster cast of a specimen from Coalbrookdale the body of which measures 5.6 cm. broad by 4.5 cm. long.

Diagnosis of *Vetacapsula moyseyi* n.sp.

Body broader than long: from 2.2 to 4.7 cm. long by 2.7 to 5.6 cm. broad, shape of a conventional heart inverted. Transition from pedicle to body comparatively sudden. Ribs shew no spiral tendency and at the widest point, towards the base of the body, are separated by 2 to 3 mm. There is a strong median ridge and the fossil is practically longitudinally symmetrical (except for the pedicle).

DISTRIBUTION

Horizon: well below the Top Hard Coal (Upper Beds of Yorkian Series).
Locality: Newthorpe Claypit, near Eastwood, Nottinghamshire (L. Moysey).

Horizon: Yorkian Series.
Locality: Coalbrookdale.

Horizon: Kilburn Coal (Lanarkian Series).
Locality: Loscoe Colliery, Derbyshire (L. Moysey).

Vetacapsula johnsoni (Kidston)

Pl. I, figs. 2, 3, 5.

Kidston's species—which he placed in the genus *Palaeoxyris*—

[1] Moysey, L., 1910, *loc. cit.*

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was based on the only specimen he had then seen. It came from Coseley, and is now in the British Museum (No. V. 1173a), while the Kidston Collection contains a plaster-cast of the fossil (No. 191). Kidston's [1] drawing of his fossil is scarcely satisfactory, and it is re-figured on Pl. 1, fig. 2. Owing to the absence of a marked spiral arrangement of the ribs, Moysey[2] suggested that the species should be referred to the genus *Vetacapsula*, and I adopt his suggestion on this and the following additional grounds:

(1) The body is more broadly fusiform than is usual in examples of *Palaeoxyris*.
(2) In the pedicle the ribs are parallel to the longer axis.
(3) There is a comparatively large number of ribs traversing the body, and the segments between them are consequently narrow.
(4) A median longitudinal ridge is present.

A careful examination of the type specimen suggests that the spiral tendency of the ribs has been accentuated, if not entirely caused, by lateral compression during fossilisation, the median ridge clearly having been displaced to one side. In those portions of the body which are crushed, the intersection of the ribs produces the effect of rhomboidal areas measuring about 1 mm. long and .8 mm. wide. The total length of the specimen is 4.8 cm., this being made up of an imperfect pedicle, a body 3.2 cm. long, and an incomplete beak of about 5 mm. Rather more than half-way down the body is situated the widest part, measuring 14 mm., and corresponding in position with the distorted area. The ribs are .5 mm. or a little less apart.

A clearer, and uncompressed, example of the species, now in the Kidston Collection (No. 908), is figured on Pl. 1, fig. 5. In this specimen also, the slight twist in the course of the ribs is probably, at least in part, accidental. The median ridge is less prominent than in the last specimen. Of four good specimens of *V. johnsoni* from Coseley, now preserved in the British Museum, the best is that figured on Pl. 1, fig. 3. The ribs on the body have a slight spiral tendency and are separated by about .5 mm. A median longitudinal ridge is present: though not well marked in this specimen, in the other three examples (Nos. V. 12600, 12601, 1173b) it constitutes a prominent feature.

Revised diagnosis of *Vetacapsula johnsoni* (Kidston)

Body broadly fusiform, from 2.2 to 4.5 cm. long and from 14 to 21 mm. broad at widest point (just below midway); average length 3.3 cm., average width 1.8 cm.; ribs numerous and closely placed (about

[1] Kidston, R., 1886, *op. cit.*, pl. I, f. 6, p. 63.
[2] Moysey, L., 1910, *op. cit.*, p. 334.

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.5 mm. apart), sometimes with a slight local tendency to a spiral arrangement; ribs in pedicle parallel. There is a more or less strong central ridge.

DISTRIBUTION

Horizon : ? Yorkian Series.
Locality : Worsborough Openworks, near Barnsley, Yorkshire (L. Moysey).

Horizon : Barnsley Thick Coal (Yorkian Series).
Locality : Barnsley, Yorkshire (L. Moysey).

Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire (H. Johnson and L. Moysey).

Horizon : above Thick Coal (Yorkian Series.)
Locality : near Bilston, South Staffordshire (C. Holcroft).

Horizon : Dunsil Coal (Yorkian Series).
Locality : Tibshelf Colliery Claypit, Derbyshire (L. Moysey).

Horizon : below Top Hard Coal (Yorkian Series).
Locality : Shipley Manor Claypit, near Ilkeston, Derbyshire (L. Moysey).

Horizon : Top Hard Coal (Yorkian Series).
Locality : Digby Claypit, Kimberley, Nottinghamshire (L. Moysey).

Horizon : Four-Foot Rider Seam (Yorkian Series).
Locality : Nantgwyn Colliery, Penygraig, Rhondda, Glamorgan (D. Davies).

Vetacapsula kidstoni n. sp.

Pl. I, figs. 7, 8.

Four specimens collected by Mr. Ware are referred to this species. They occur in shale and are as follows :

No. R. C. 245 (and counterpart R. C. 246).
Horizon : Rhyd Vein (Yorkian Series).
Locality : Upper Cwm-Tawe Colliery, Abercrave, South Wales.

No. R. C. 248 (bearing two specimens) and No. R. C. 247.
Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Ystradgynlais, near Swansea.

Associated with R.C. 245 are twigs of *Lepidodendron lycopodioides* Sternb. and fragments of shells which are identified by Mr. J. Pringle as those of fresh-water lamellibranchs. The total length of the fusiform specimens varies from 1.8 to 2.8 cm., while they are from 5 to 6 mm. wide. The pedicle and beak merge so gradually into the body that it is difficult to determine their exact limits, but in the fairly complete specimen (R.C. 248) the total length of 2.8 cm. is made up of, pedicle (about) 9 mm., body (about) 14 mm., and beak (about) 5 mm. Both beak and pedicle take a slightly oblique course. There is practically no tendency towards the spiral arrangement of the ribs. The beak is incomplete in all four specimens. Across the widest part of the body (that is, slightly below its centre) are from 8 to 12 ribs, about .5 mm. apart. A central ridge is absent from these specimens and the body is non-symmetrical in the longitudinal direction. In this connection it is interesting to note that most specimens of *Vetacapsula* show a fair degree of correspondence

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between the strength of the central ridge and the approach to longitudinal symmetry, while in *Palaeoxyris* the fossil is longitudinally symmetrical in the absence of a median ridge. In *V. kidstoni* there is the usual distorted region below the centre of the body, and this area has a granular appearance in specimen R.C. 247. The latter example also bears, below the commencement of the beak, a rounded protuberance similar to those described by Moysey[1] as occurring on *Palaeoxyris helicteroides*, and regarded by him as indicating infection by parasitic organisms.

V. kidstoni stands near to *V. minima* Moysey[2] (collected from above the Fiddler's Vein (Yorkian Series) at Bridge Patch, between Wiseman's Bridge and Amroth) but the ribs are about twice as wide apart, while there is no median longitudinal ridge. Moysey described a marked central ridge in his specimen and thought[3] 'the fossil was not truly cylindrical, but that it had two, or possibly four, angles in the contour of its transverse section.' He compared *V. minima* with a specimen collected by Mr. W. Hemingway from below the Haigh Moor Coal (Yorkian Series) at Brightside, Sheffield, in which the ribs were about 1 mm. apart[4]. Both *V. minima* and *V. kidstoni* are separable from *V. johnsoni* in point of size and in the number of ribs present.

A small, uncrushed form, somewhat similar to *V. kidstoni*, was figured in 1927 by Chabacov[5] from the Carboniferous of Russia, under the name *V. czernyshevi*, this being the first record of the genus from outside Great Britain. From Chabacov's line drawing, it is evident that the fossil is .6 cm. wide at the broadest point, while the body measures 1.8 cm. in length; there are 10 ribs about .6 mm. apart. The latter are slightly spiral (as in *V. johnsoni*), and the body is non-symmetrical in the longitudinal direction. There is no sign of a central ridge. While the pedicle is well represented (bearing parallel ribs), the beak is not preserved. This specimen differs from *V. kidstoni* in size and in the spiral twist given to the ribs.

Diagnosis of *Vetacapsula kidstoni* n.sp.

Body fusiform, not symmetrical, about 1.4 cm. long and 5 to 6 mm. wide, very gradually tapering above into the beak and below into the pedicle. The widest part of the body has 8-12 ribs which are about .5 mm. apart; they follow the contour of the body and are not in spirals. There is no median longitudinal ridge.

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[1] Moysey, L., 1910, *op. cit.*, p. 334.
[2] Moysey, L., 1913, in Goode, R. H., 'On the Fossil Flora of the Pembrokeshire Portion of the South Wales Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxix, pp. 266, 267, pl. xxx, f. 3. It has not been possible to examine this specimen.
[3] *Loc. cit.*
[4] Moysey (*loc. cit.*) observed that this specimen was in the Kidston Collection, but it is not now there, and I have not been able to trace it.
[5] Chabacov, A. W., 1927, *loc. cit.*

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BRITISH SPECIES OF *VETACAPSULA*

(The chief diagnostic features are marked by an asterisk).

	V.cooperi Mackie	*V.moyseyi* n. sp.	*V.johnsoni* (Kidston)	*V.kidstoni* n. sp.	*V.minima* Moysey
Shape of body	* broadly fusiform ; longer than broad	* conventional heart inverted ; broader than long	broadly fusiform	fusiform	fusiform
Expansion of pedicle	* fairly gradual, forming no ' shoulder '	* sudden, forming a ' shoulder '	* fairly gradual	* very gradual	very gradual
Breadth of body	2.5-4.6 cm. (av. 3 cm.)	2.7-5.6 cm.	* 1.4-2.1 cm. (av. 1.8 cm.)	* .5-.6 cm.	.5 cm.
Length of body	2.5-4.9 cm. (av. 3.5 cm.)	2.2-4.7 cm.	* 2.2-4.5 cm. (av. 3.3 cm.)	* 1.4 cm.	1 cm.
Longitudinal symmetry of body	symmetrical	symmetrical	variable	* non-symmetrical	* symmetrical
Number of ribs	17-25	16-26	* 35-60	* 8-12	20
Distance between adjacent ribs	1.1-2.5 mm.	2-3 mm.	* .4-.6 mm.	* .5 mm.	* .25 mm.
Course of ribs	not spiral	not spiral	sometimes slightly spiral	not spiral	not spiral
Median ridge	present, strong	present, strong	present, varies in strength	* absent	* present, strong
Figured	pl. 1, figs. 1, 4.	pl. 1, fig. 6.	pl. 1, figs. 2, 3, 5.	pl 1, figs. 7, 8.	Q.J.G.S., lxix pl. xxx, fig. 3.

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SPECIES OF *PALAEOXYRIS*

Palaeoxyris helicteroides (Morris)

Pl. II, figs. 4, 9.

In 1840 Morris[1] gave a short description of this the commonest British species of *Palaeoxyris* under the name *Carpolites helicteroides*, believing it to be a fruit. Kidston[2] somewhat amplified Morris' account in 1886, but Moysey's[3] description of 1910 requires little comment. One of the two syntypes is re-figured on Pl. II, fig. 4.

The fossils are composed of 8 segments, 4 narrow alternating with 4 broad bands, a construction which separates this from all other known species of the genus (in which the segments are all of approximately equal breadth). The angle at which the ribs arise varies between 45 and 60 degrees. The pedicle is invariably traversed by spirally arranged ribs, but those in the beak are roughly parallel to its longer axis, converging towards the pointed apex. In recording an incomplete specimen of *P. helicteroides* from the Bristol Coalfield, Dr. H. Bolton[4] observed that the ribs were spirally arranged in the beak, but a re-examination of the fossil (Bristol Museum, No. C. 973) leaves no doubt that the part referred to is the pedicle, and Dr. Bolton has written expressing agreement with this. Though it is usually straight, the pedicle is not infrequently curved. In perfectly preserved specimens, which are rare, the beak is almost as long as the body (about 2.5 cm., e.g., in Nos. Za 2578, 2637, Museum of Practical Geology), and, as Moysey observed, ' It has a slight twist on itself, like that on the blade of a ship's propeller '. Thus, while in transverse section the body was roughly circular, the beak was a flattened organ. The deformed area occurs just below the centre of the body. While the body of average specimens measures about 3.2 cm. in length and 1.2 cm. in breadth, the length may be as small as 2.6 cm. or as large as 6 cm., and the width varies from .7 to 3 cm.

DISTRIBUTION

Previous records.

Horizon : Swansea Four-foot Seam (Radstockian Series).
Locality : Tip at Cae-newydd Colliery, about 1 mile N. of E. of Gowerton Station, South Wales. (J. Pringle).

Horizon : 279 feet below Bedminster Great Vein (Staffordian Series).
Locality : South Liberty Colliery, Bedminster, Bristol (H. Bolton—Collection of Bristol Musuem).

Horizon : Yorkian Series.
Locality : Coalbrookdale, Shropshire (Morris' syntypes).

Horizon : Yorkian Series.
Locality : Madeley Court, Shropshire (R. Kidston).

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[1] Morris, J., 1840, in Prestwich, J., ' On the Geology of Coalbrookdale, ' *Trans. Geol. Soc. Lond.*, 2nd Ser., vol. v, Expl. to f. 12, 12 a, pl. xxxviii.
[2] Kidston, R., 1886, *op. cit.*, p. 60.
[3] Moysey, L., 1910, *op. cit.*, p. 331.
[4] Bolton, H., 1911, ' Faunal horizons in the Bristol Coalfield, ' *Quart. Journ. Geol. Soc.*, vol. lxvii, p. 316, pl. xxvii, f. 20, 21.

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Horizon : Top Hard Coal (Yorkian Series).
Localities : Shipley Manor Claypit, near Ilkeston, Derbyshire (L. Moysey—Kidston Collection, No. 4152 ; Digby Claypit, Kimberley, Nottinghamshire (L. Moysey—Kidston Collection, No. 4153).

Horizon : Combe Coal, above Top Hard Coal (Yorkian Series).
Locality : Brindsley Claypit, Eastwood, Nottinghamshire (L. Moysey).

Horizon : Waterloo Coal (Yorkian Series).
Locality : Meadow Lane Claypit : Alfreton (L. Moysey).

Horizon : Ten-foot Ironstone Measures (Yorkian Series).
Locality : Clays Croft Openworks, Coseley, Dudley, Staffordshire (H. W. Hughes—Kidston Collection Nos. 6976, 6977, 6979 ; J. Johnson, No. 6980).
Horizon : Coal Measures (?Yorkian Series).
Locality : Bilston, South Staffordshire.

Horizon : Thick Coal (Yorkian Series).
Locality : Clays Croft Openworks, Coseley, Dudley (H. W. Hughes—Kidston Collection, No. 6981).
Horizon : ?
Locality : Bardsley Colliery, Ashton-under-Lyne, Lancashire (G. Wild—Kidston Collection No. 6978).

Horizon : Fairbottom Mine Coal (of the Bardsley Colliery).
Localities : Hill-pit, Limeside, Bridge Pit, Knott Lane (G. Wild—Collection of Manchester Museum) ; Wood Park ¼ mile west of Bardsley, Lancashire (J. Nield—Collection of Oldham Museum).
Horizon : ?
Locality : Chamber Pits, Fitton Hill, near Oldham (R. Cairns—Collection of Manchester Museum).

Horizon : Barnsley Coal (Yorkian Series).
Locality : Yorkshire.

Additional Records.

Horizon : Barnsley Thick Coal (Yorkian Series).
Localities : Round Green Colliery, Barnsley, Yorkshire (Collection of W. R. Barker of Barnsley) ; Worsborough, near Barnsley (Collection of Barnsley Nat. and Sci. Soc.)

Horizons : 1,896 and 2,174 ft. from surface (Yorkian Series).
Locality : Thom Borehole, Cwmgorse, 3½ miles N.W. of Pontardawe, South Wales (E. Dix and A. E. Trueman).

Horizon : 2,285 ft. from surface (Yorkian Series).
Locality : Trefor Boring, Cwmgorse, South Wales (E. Dix and A. E. Trueman).
Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Gurnos Anthracite Colliery, Ystradgynlais, Swansea (W. D. Ware).
Horizon : ?
Locality ; Ynyscedwyn Colliery, Ystradgynlais, Swansea (W. D. Ware).

Horizon : Lanarkian Series.
Locality : Woodhill Quarry, Kilmaurs, Ayrshire (D. Landsborough, Kidston Collection No. 593).

Palaeoxyris carbonaria Schimper

Pl. II, fig. 8.

The fusiform body, normally composed of 6 to 8 equally broad segments, varies in length from 2.6 to 3.2 cm., and in width from .8 to 1.2 cm., average specimens measuring 3 cm. long by 1.1 cm. broad. The ribs cross it at an angle of 30 degrees and are separated by about

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2 mm. (occasionally less). Kidston[1] expressed some doubt as to which extremity represented the 'base' (=pedicle) and which the 'apex' (=beak) of one of the specimens he figured. It is clear, however, that the longer extremity, consisting of twisted segments, (and which is marked 'a' in his figure) is the pedicle.

In the British Museum are two specimens from Coseley (Nos. V. 12925, V. 12928) which agree fairly well with this species in most respects, but bearing ribs 1 mm. apart, or even slightly less (and being consequently more numerous than in typical examples of the species). This type may be distinguished as *P. carbonaria* forma α. *P. carbonaria* is very rare in Britain, but White[2] observed that *P. appendiculata* Lesqx.,[3] which was regarded by Kidston[4] and others as synonymous with *P. carbonaria*, appeared to be the commonest American species of the genus. White, however, did not agree with the union of these two species, observing that *P. appendiculata* is distinguished from *P. carbonaria* 'by the narrower valves,[5] and consequently smaller areolation in compressed specimens; and while in *P. appendiculata* the whole organ is, in general, smaller, the dilated portion is proportionally larger'. It should be pointed out, however, that, in describing his type specimen, Lesquereux gave one twelfth of an inch as the average width of the segments, while in *P. carbonaria* they average 2 mm. The two species should, in my opinion, be united.

Distribution

Previous Records.

Horizon: Ten-foot Ironstone Measures (Yorkian Series.)
Locality: Clays Croft Openworks, Coseley, Dudley, Staffordshire (H. W. Hughes and J. Ward—Kidston Collection Nos. 6973, 6974).

Horizon: above Top Hard Coal (Yorkian Series).
Locality: Digby Claypit, Kimberley, Nottinghamshire (L. Moysey).

Horizon: above Barnsley Coal (Yorkian Series).
Locality: Yorkshire.

Horizon.: Lanarkian Series.
Locality: Woodhill Quarry, Kilmaurs, Ayrshire (D. Landsborough—Kidston Collection No. 6975).

Additional Records.

Horizon: 647 feet from surface (Radstockian Series, Keele Beds).
Locality: Claverley Boring, Shropshire (Museum of Practical Geology No. 44691).

Horizon: between Brooch and Thick Coals (Yorkian Series).
Locality: Coseley, near Dudley. (L. Moysey—Bristol Museum, No. Cb. 1566).

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[1] Kidston, R., 1886, *op. cit.*, pp. 61-62, pl. 1, f. 2.
[2] White, D., 1889, 'Fossil Flora of the Lower Coal Measures of Missouri,' *U.S. Geol. Surv.*, vol. xxxvii p. 274.
[3] Lesquereux, L., 1870, *Geol. Surv. Illinois*, vol. iv, p. 464, pl. xxvii, f. 11.
[4] Kidston, R., 1886, *op. cit.*, p. 61, and Moysey, L., 1910, *op. cit.*, p. 330.
[5] The term 'valves', as here used, is equivalent to the term 'segments' as employed in the present and in most recent papers.

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Horizon : Coal Measures.
Locality : Sliddery Water Head, Burn ' B,', south of road (Coll. Geol Surv. Scottish Office, No. 3547).

Horizon : Mynyddislwyn Vein. (Radstockian Series).
Locality : Gelli-deg-level, Maes-y-cwmmer, Monmouthshire (J. Pringle—Museum of Practical Geology, No. J. P. 202).

Horizon : Green Vein (Yorkian Series).
Locality : Trimsaran, Carmarthen (E. Dix and A .E. Trueman).

Palaeoxyris prendeli Lesqx.

Pl. II, fig. 7.

In this very rare species the fusiform body varies in length from 2.5 to 3.4 cm., and in breadth from 1.2 to 1.8 cm. There are from 4 to 8 equal segments 2.5 to 6 mm. wide. The angle at which the ribs arise is usually 45-55 degrees.

DISTRIBUTION

Horizon : Yorkian Series.
Locality : Clays Croft Openworks, Coseley, Dudley, Staffordshire. (H. W. Hughes—Kidston Collection, Nos. 190, 192).

Horizon : Top Hard Coal (Yorkian Series).
Locality : Shipley Claypit, near Ilkeston, Derbyshire (L. Moysey—Kidston Collection No. 4151, and H. S. Holden).

Horizon : well below Top Hard Coal (Yorkian Series).
Locality : Newthorpe Claypit, near Eastwood. Nottinghamshire. (L. Moysey).

Horizon : Combe Coal, above Top Hard Coal (Yorkian Series).
Brindsley Claypit, Eastwood, Nottinghamshire (L. Moysey).

Horizon : Yorkian Series.
Locality : Yorkshire.

Horizon : Arley Mine Coal (Yorkian Series).
Locality : Sparth Bottoms Claypit, Rochdale, Lancashire (L. Moysey and W. A. Parker).

Palaeoxyris trispiralis Kidston

Pl. II, fig. 1.

Kidston's[1] type specimen, with its counterpart, is preserved in the British Museum (Nos. V. 1179 and 6364 respectively), the counterpart being figured on Pl. II, fig. 1. The fossil has a total length of about 12 cm., of which 9 cm. is occupied by the body, 1.7 cm. by the pedicle, and 1.7 cm. by the beak. There are 3 segments, each about 9 mm. across, and the body measures from 3 to 3.4 cm. in width. The small number and great width of the segments are characteristic. By their intersection the ribs, which arise at an angle of 30-40 degrees, divide the segments into rhomboids 16 to 18 mm. broad by 10 to 12 mm. high.

Sutcliffe[2] recorded a specimen, (now in the Manchester Museum,

[1] Kidston, R., 1886, *op. cit.*, pl.I, fig. 7, p. 64.
[2] Sutcliffe, W. H., 1909, 'Notes on *Palaeoxyris prendeli* (Lesquereux), from the Middle Coal Measures, Sparth, Rochdale,' *Lancashire Naturalist*, July, 1909, p.117, text-fig. 3, p. 116.

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No. L. 9128) from the Second Grit Flagstone of Ashworth Moor, near Rochdale, which he referred to this species. Describing it as an uncompressed example, he gave the width as 30 mm., but it is actually partially compressed, and consequently elliptical in transverse section, and, while the greater axis measures (nearly) 30 mm., the smaller, including the raised ribs, is only 20 mm. I have grave doubts as to the attribution of this specimen to Kidston's species; the body appears to be composed of more than the typical 3 segments and the ribs arise at an angle of only 15 degrees. The specimen is smaller and the segments narrower (7 mm.) than in the type specimen.

DISTRIBUTION:

Horizon: Yorkian Series.
Locality: Coseley, near Dudley, Staffordshire (H. Johnson).

Palaeoxyris warei n.sp.

Pl. II, fig. 6.

The fossil (No. R.C. 256) on which this species is based is one of a number collected by Mr. W. D. Ware of Ystradgynlais, Swansea. On the same slab as the specimen are numerous plant-fragments, including *Sphenophyllum cuneifolium* Sternb., *Neuropteris heterophylla* Brongt., *Calamites sp.*, *Asterophyllites charaeformis* (Sternb.), and *Pinnularia capillacea* (L. & H.). In general aspect the specimen resembles *P. trispiralis* Kidston, prominent angles being formed by the meeting of the ribs along its margin. Kidston's species, however, is much larger, the body measuring 9 cm. in length by 3 to 3.4 cm. in breadth, while the present specimen is only 1.8 cm. long by .7 cm. broad. In *P. trispiralis* the ribs arise at an angle of from 30 to 40 degrees, while in *P. warei* the angle is about 30 degrees. Three segments compose the body of the former, while 6 are found in the latter species. The width of the segments is similarly distinctive, being approximately 9 mm. in *P. trispiralis* and 1.5 to 1.8 mm. in *P. warei*. In the latter species also the expansion of the margins in passing from the pedicle to the body is noticeably less rapid. The specimen shows only a small portion of the beak, but the constriction of the neck and the central narrow segment of the beak are clearly seen. About 1 cm. of the pedicle, which was 2 mm. wide, is preserved.

Diagnosis of *Palaeoxyris warei* n.sp.

Body narrowly fusiform, 1.8 cm. long by 7 mm. broad, consisting of 6 equal segments, 1.5-1.8 mm. wide. Ribs arise at an angle of about 30 degrees. Expansion from pedicle to body very gradual.

Horizon: Yorkian Series.
Locality: Gwaunclawdd Colliery, Abercrave, South Wales.

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Palaeoxyris pringlei n.sp.

Pl. II, fig. 2.

This specimen (No. 38557), though well-preserved, is unfortunately not quite complete. It was collected by Dr. L. J. Wills and at the time was provisionally identified by Mr. J. Pringle as a new species of *Palaeoxyris* allied to *P. carbonaria* Schimper. The angle at which the ribs arise is characteristically low, being about 15 degrees. The body is fairly broadly fusiform; it measures 1.8 cm. in length (and, if complete would probably have reached 2.2 cm. or so). Its margins expand fairly rapidly to a maximum breadth of 1 cm. The ribs are from .8 to 1 mm. apart, producing by their intersection small rhomboids which are two or three times as broad as they are high. There are about 14 equally broad segments, as compared with 6 to 8 in *P. carbonaria*. The specimen is somewhat smaller than those of the latter species, the ribs arise at a lower angle, are more closely placed, and more numerous. The beak is complete, measuring about 2 cm. in length, and having a long, almost hair-like point. The pedicle is missing. I have much pleasure in naming this species after Mr. J. Pringle.

Diagnosis of *Palaeoxyris pringlei* n.sp.

Body fairly broadly fusiform, about 2.2 cm. long by 1 cm. broad, composed of about 14 equally broad segments: ribs .8 to 1 mm. apart, arising at an angle of 15 degrees: beak 2 cm. long.

Horizon: Shales below Half-yard Coal of the Coed-yr-allt or Morlas Coals, Coed-yr-allt Series (Newcastle-under-Lyme Group of the Staffordian Series).

Locality: Above the small bridge and about 140 yds. from the Morlas, up the stream flowing from Pentre to Glyn Morlas, near Chirk, N. Wales.

Palaeoxyris edwardsi n.sp.

Pl. II, fig. 3.

Among the specimens collected by Mr. Ware is one (No. R.C. 255) which I name after Mr. W. N. Edwards of the British Museum (Natural History). It measures only 2 cm. in length (though not quite complete) and is the smallest known British species of the genus. The maximum width is 3.5 mm., and the very narrowly fusiform body consists of 5 equally broad segments measuring 1 mm. across. The ribs are more steep than in most species of *Palaeoxyris*, arising at an angle of about 80 degrees, the only British species approaching *P. edwardsi* in this respect being *P. helicteroides*, a fossil with which it could not be confused. The specimen is compressed, and the rhomboids produced by the intersection of the ribs are 4 or 5 mm. high by about 1 mm. wide.

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Diagnosis of *Palaeoxyris edwardsi* n.sp.

Body narrowly fusiform, about 2.2 cm. long by 3.5 mm. wide, composed of 5 equally broad segments 1 mm. broad : angle formed by the ribs 80 degrees, rhomboids much higher than broad.

Horizon : ? Yorkian Series.
Locality : Yniscedwyn Colliery, Ystradgynlais, Swansea.

? Palaeoxyris sp.

Pl. II, fig. 5.

A specimen in shale (No. R.C. 252), collected by Mr. Ware from an unknown horizon at the International Colliery, Abercrave, South Wales, I regard as possibly representing a specimen of *Palaeoxyris* embedded in the vertical position. It is associated with plant-remains and a fragment of a shell which Mr. J. Pringle identifies as that of a fresh-water lamellibranch. The impression is elliptical in shape. The longer axis measures 10 mm. and the shorter 9 mm., and the specimen thus conforms in size with several British Palaeozoic species of *Palaeoxyris*.

A carbonaceous covering at the margin extends inwards for 1 or 2 mm., where it is broken in an irregular manner, revealing a blunt depressed central point from which several slightly curved lines radiate out to the circumference. The central point may represent either the beak or the pedicle extremity in horizontally embedded examples of the genus, while the radiating lines may correspond to the ribs. The specimen is here figured in order to draw attention to this type of fossil.

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BRITISH PALAEOZOIC SPECIES OF *PALAEOXYRIS*.

(The chief diagnostic features are marked by an asterisk)

	P.helicteroides (Morris)	*P.carbonaria* Schimper	*P.prendeli* Lesqx.	*P.trispiralis* Kidston	*P.warei* n.sp.	*P.pringlei* n.sp.	*P.edwardsi* n.sp.
Shape	fusiform	fusiform	fusiform	fusiform	narrowly fusiform	fairly broadly fusiform	very narrowly fusiform*
Length of body	2.6-6 cm. (av. 3.2 cm.)	2.6-3.2 cm. (av. 3 cm.)	2.5-3.4 cm.*	9 cm.*	1.8 cm.*	about 2.2 cm.	2 cm.*
Width of body	.7-3 cm. (av. 1.2 cm.)	.8-1.2 c.m (av. 1.1 cm.)	1.2-1.8 cm.*	3-3.4 cm.*	.7 cm.*	1 cm.	3.5 mm.*
Number of segments	8	6-8	4-8	3*	6*	14	5
Width of segments	alternately broader and narrower ; broad, 4-5 mm. narrow, 1-1.5 mm.*	equally broad, 2 mm. (1 mm. in forma α)*	equally broad, 2.5-6 mm.*	equally broad, 9 mm.*	equally broad, 1.5-1.8 mm.*	equally broad, .8-1 mm.	equally broad, 1 mm.*
Angle of ribs	45-60 deg.	30 deg.*	45-55 deg.*	30-40 deg.	30 deg.	15 deg.*	80 deg.*
Expansion from pedicle to body	gradual	gradual	sudden	fairly sudden	very gradual	fairly sudden	very gradual
Rhomboids (in compressed specimens).	of two sizes	as long as broad (about 2 mm.)*	slightly broader than long (5-9 mm. broad 4-6 mm. long)*	broader than long (16 mm. broad, 11 mm. long)	broader than long (3 mm. broad, 2 mm. long)	much broader than long (2.5-3 mm. broad, 1 mm. long)	much longer than broad (1 mm. broad, 4-5 mm. long)
Figured	pl. II, f. 4, 9.	pl. II, f. 8.	pl. II, f. 7.	pl. II, f. 1.	pl. II, f. 6.	pl. II, f. 2.	pl. II, f. 3.

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Explanation of Plate I

Fig. 1.—*Vetacapsula cooperi* Mackie.
Horizon : ? Coal Measures.
Locality : unknown.
Collector : C. W. Crocker.
Collection : British Museum (Natural History) No. V.5149 (Mackie's type specimen). x 1.

Fig. 2.—*Vetacapsula johnsoni* (Kidston).
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1173a (Kidston's type specimen). x 2.

Fig. 3.—*Vetcapsula johnsoni* (Kidston).
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collection : British Museum (Natural History) No. V. 12929. x 1½.

Fig. 4.—*Vetacapsula cooperi* Mackie.
Horizon : Furnace Coal (Yorkian Series).
Locality : Cossall Claypit, Nottinghamshire.
Collector : L. Moysey.
Collection : Museum of Practical Geology No. 47923. x 1.

Fig. 5.—*Vetacapsula johnsoni* (Kidston).
Horizon : above Thick Coal (Yorkian Series).
Locality : near Bilston, South Staffordshire.
Collector : C. Holcroft.
Collection : Kidston Collection No. 908. x 1.

Fig. 6.—*Vetacapsula moyseyi* n.sp.
Horizon : Kilburn Coal (Lanarkian Series).
Locality : Loscoe Colliery, Derbyshire.
Collector : L. Moysey.
Collection : Museum of Practical Geology No. 47925. x 1.

Fig. 7.—*Vetacapsula kidstoni* n.sp.
Horizon : Rhyd Vein (Yorkian Series).
Locality : Upper Cwm-Tawe Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 245. x 2¾.

Fig. 8.—*Vetacapsula kidstoni* n.sp.
Horizon : Brass Vein (Yorkian Series).
Locality : Diamond Slant, Ystradgynlais, near Swansea.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 248. x 2.

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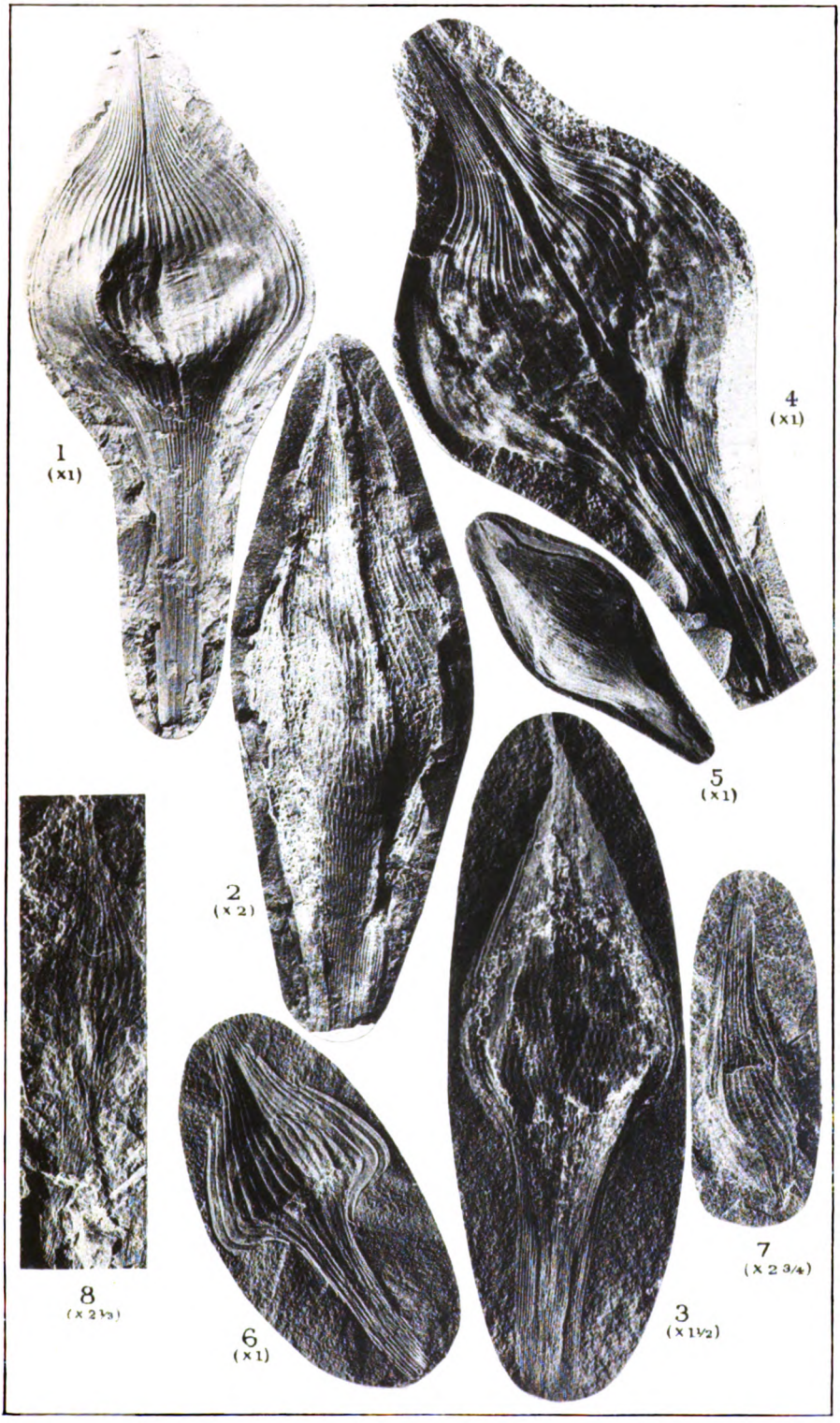

VETACAPSULA.

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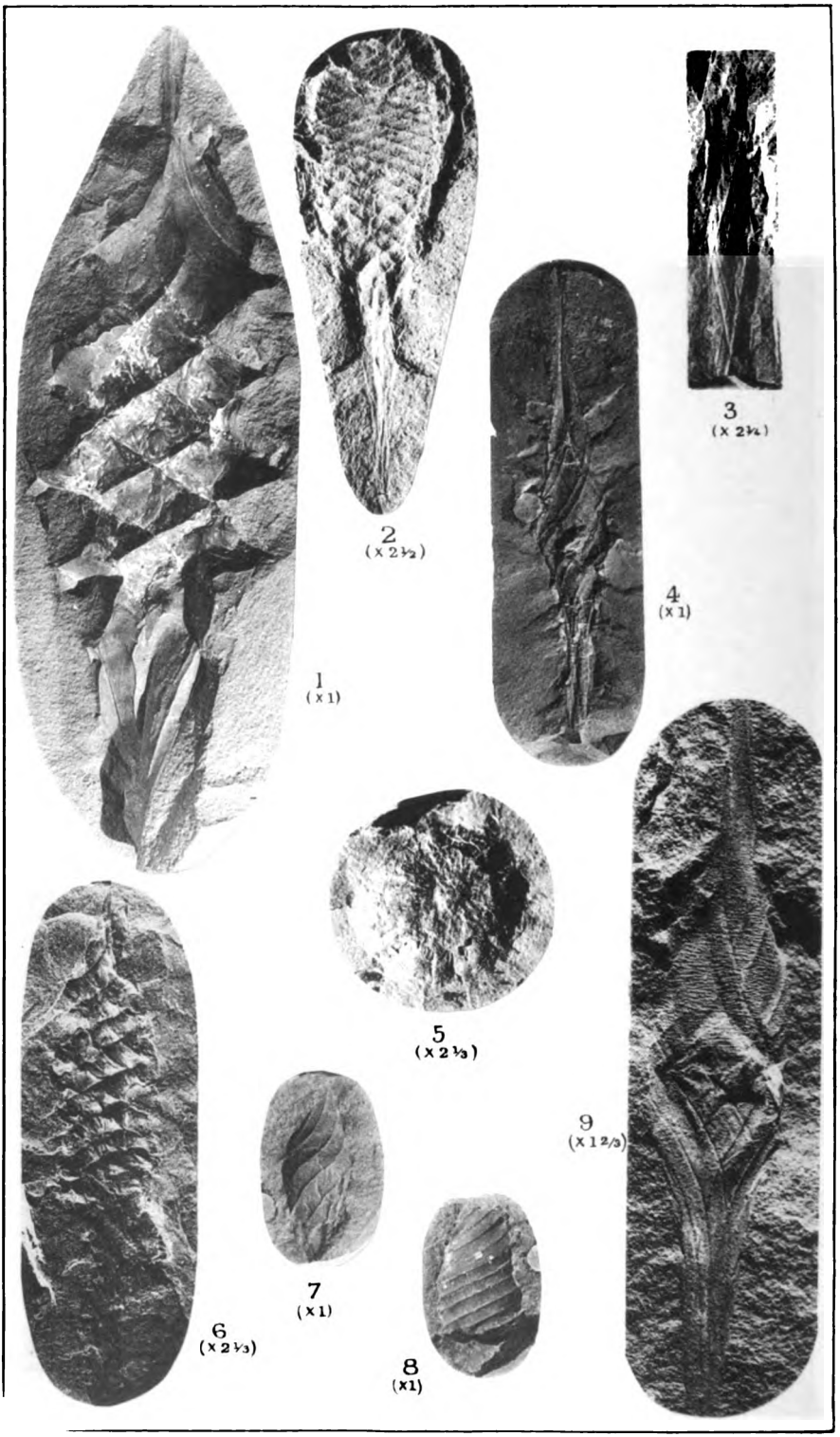

PALAEOXYRIS.

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Explanation of Plate II

Fig. 1.—*Palaeoxyris trispiralis* Kidston.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.6343 (counterpart of Kidston's type specimen). x 1.

Fig. 2.—*Palaeoxyris pringlei* n.sp.
Horizon : below Half-yard Coal of the Coed-yr-allt or Morlas Coals, Coed-yr-allt Series (Newcastle-under-Lyme Group of the Staffordian Series).
Locality : above the small bridge and about 140 yds. from the Morlas, up the stream flowing from Pentre to Glyn Morlas, near Chirk, North Wales.
Collector : L. J. Wills.
Collection : Museum of Practical Geology No. 38557. x 2½.
(N.B. The beak of this specimen is pointing downwards on the plate.)

Fig. 3.—*Palaeoxyris edwardsi* n.sp.
Horizon : ? Yorkian Series
Locality : Yniscedwyn Colliery, Ystradgynlais, near Swansea.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R.C. 255. x 2½.

Fig. 4.—*Palaeoxyris helicteroides* (Morris).
Horizon : Yorkian Series.
Locality : Coalbrookdale.
Collector : J. Morris.
Collection : British Museum (Natural History) No. V.4259 (one of the two syntypes). x 1.

Fig. 5.— ? *Palaeoxyris* sp.
Horizon : ?
Locality : International Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 252. x 2¾.

Fig. 6.—*Palaeoxyris warei* n.sp.
Horizon : ? Yorkian Series
Locality : Gwaunclawdd Colliery, Abercrave, South Wales.
Collector : W. D. Ware.
Collection : Museum of Practical Geology No. R. C. 256. x 2¾.

Fig. 7.—*Palaeoxyris prendeli* Lesqx.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1177. x 1.

Fig. 8.—*Palaeoxyris carbonaria* Schimper.
Horizon : Yorkian Series.
Locality : Coseley, near Dudley, Staffordshire.
Collector : H. Johnson.
Collection : British Museum (Natural History) No. V.1178 x 1.

Fig. 9.—*Palaeoxyris helicteroides* (Morris).
Horizon : Coal Measures (? Yorkian Series).
Locality : Bilston, South Staffordshire.
Collection : British Museum (Natural History) No. V.4260 x 1¼.

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Department of Scientific and Industrial Research

Summary of Progress

of the

Geological Survey of Great Britain

and the

Museum of Practical Geology

for the Year 1928

PART I

With Report of the Geological Survey Board and Report of the Director

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REPORT OF THE GEOLOGICAL SURVEY BOARD FOR 1928

TO THE LORDS OF THE COMMITTEE OF THE PRIVY COUNCIL FOR SCIENTIFIC AND INDUSTRIAL RESEARCH

MAY IT PLEASE YOUR LORDSHIPS.—

In accordance with our terms of reference, we, the Geological Survey Board, beg to submit our Ninth Annual Report on the work of the Survey and Museum.

Personnel

1. We desire to record our high appreciation of the personnel and organisation of the staff of the Geological Survey and Museum. To this service, in these days, there falls work of great variety and the qualifications of its members are high. Its organisation facilitates an allocation of duties that takes account of the fitness of individuals for particular types of work and makes provision for meeting promptly a call for concentration on one matter or another. The standard for recruitment has been fully maintained throughout the expansion of duties and the increase of establishment that have marked the past ten years.

Accommodation (London)

2. **Headquarters.**—The inadequacy of the accommodation in the Headquarters offices in Jermyn Street causes serious difficulties for every section of the staff—not least for the members of the field staff who have there, in the winter months, to work up the results of their field work with full opportunities of access to collections and records and of consultation with their colleagues. The gradual increase in the volume of the services the Survey provides, and the need for early and adequate records of all information collected, have made crowding inevitable. The congestion that now obtains is a serious handicap on these services and it ought to be relieved as early as possible. From no point of view is the early provision of a new building more urgent than as an essential to the full utilisation of the work of the staff.

Museum.—In Section 34 of their Interim Report the Royal Commission on National Museums and Galleries deal at length with the position of the Museum of Practical Geology. We are glad to note their strong recommendation that a new Museum on lines already discussed and approved by us should be erected at South Kensington. We understand that early action is to be taken on this recommendation.

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In the evidence he submitted to the Royal Commission, the Director of the Geological Survey and Museum gave a clear statement as to the origin, aims and practice of the Museum and as to the nature and extent of the accommodation it requires.

Established as the 'Museum of Practical Geology,' the museum has consistently aimed at illustrating the work of investigators in the Geological Sciences and the relation of the results of such work to current advances in the practice of those who are primarily concerned in forwarding mining, quarrying, metallurgy, communications, sanitation and the many other activities that are concerned with either the deep or the surface deposits of this country. Such illustration is required both for ready exposition of dominant factors in geological conditions and for reference by those who study the detailed information available in the map rooms and libraries of the Survey and Museum in relation to particular scientific and economic interests. Adequate illustration of this kind is indeed essential to the effective publicity of the results of the Survey work.

Further, as it happens, not a few of the most productive advances in the knowledge of geological structure and sequence originated in this country, and the work of the investigators who pointed the way in such new departures is now classic. As the national museum of British Geology, this museum interests all British geologists at home or from overseas; it also attracts every foreign geologist who visits this country. For all such visitors the exposition the Museum provides under this category is a matter of primary value. For effective exposition the first necessity is good exhibition space. In the present building this is gravely deficient; in the new building it will be worthy of the material to be shown, and the examples available will fittingly illustrate the work of the great pioneers with whose names they are associated. In various sections of investigation these names range from that of William Smith—'The father of stratigraphical geology'—at the beginning of the XIXth century, to those of Lapworth, Peach and Horne who in solving, as they did at the end of the century, the complex riddles presented by the schists and gneisses of the North-west Highlands of Scotland, made contributions of the first rank to recent advances in the science.

Accommodation (Scottish and Provincial Offices)

3. The provision for the accommodation of the Scottish Headquarters at Southpark in Edinburgh is excellent except as regards storage space, and we hope that this defect will be made good in the near future.

The branch offices at York, Manchester and Newcastle-on-Tyne are maintained.

Field Work

4. The Director's Report for 1928, which is submitted herewith, shows that the stated programme of field work for the year has been

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carried out and that good progress has been made in the improvement of methods of survey and enquiry, in promoting the ready use of accumulated information of geological value in relation to industries, and in the methods of presenting the results of the work of the Survey.

The Field Units have been engaged on surveys of ten districts as prescribed in the programme approved for the year, viz. :—

Southern District (primary six-inch survey).
Midlands District (primary six-inch survey).
Yorkshire District (revision of six-inch survey).
Lancashire District (revision of six-inch survey).
Cumbrian District (revision of six-inch survey).
Northumberland and Durham District (revision of six-inch survey).
Ayrshire (revision of six-inch survey).
Lanarkshire and Peeblesshire (revision of six-inch survey).
Fife and Kinross (revision of six-inch survey).
Orkney Islands (primary six-inch survey).

Details of the work carried out by each of these Field Units are given in the *Summary of Progress* (pp. 54-83).

Attention was also given to certain sections of the South Wales Coalfield with a view to the revision of the six-inch mapping and the preparation of Vertical Sections embodying the results of recent work. Revised editions of some of the relevant sections are now in the press.

Work involved in the Issue of Maps and Memoirs

5. Alike in respect of the primary six-inch survey work and of the revision of the maps for coalfield and residential areas, we regard the progress as highly satisfactory. The one-inch maps are now issued in well considered colour-printed form and at a low price. These and the new or revised Memoirs on the geology of each area, give publicity to the results of the work of the Survey, and they lead those who are interested on points of detail to the primary six-inch records of which many are published and all are available for reference.

The issue of one-inch maps affords a fair measure of the current activities of the Survey in field work, and from this point of view it is noteworthy that in the past year an exceptionally large number of the English one-inch maps passed through the press.

Each one-inch map issue involves not only careful study by the Field Staff—mapping or revision of earlier mapping, collection of specimens and of records of earlier observations, examination of geological conditions as affecting industry or residence—but also consultation with fellow workers and specialists, and subsequently in the office, detailed description in memoirs and careful preparation for the printer.

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Thus, in the ordinary routine of work the issue of a new or a revised one-inch-to-the-mile map normally marks the completion of a definite area of field work by the field staff engaged on it, and the result of the active co-operation of not a few who may never have seen the area. Equal areas vary greatly in complexity of structure and therefore in the time and study for which they call.

The replacement of the one-inch hand-coloured maps by the less costly colour-printed editions has been progressing steadily. Already, for England and Scotland alike, one third of the 'one-inch' scale sheets are obtainable in the colour-printed form—and these maps are not only cheaper but also, in several respects, better, than the previous hand-coloured maps.

Surveys and Records

6. The primary survey of every area is made on maps to a scale of six inches to a mile, and from these original maps, or from later revisions of them, the universal 1-inch-to-1-mile geological maps are reduced. Copies of the 6-inches-to-1-mile geological maps and many valuable records are held available for reference at the Headquarters Offices concerned. For the coalfield areas, however, the six-inch maps are also published. In the past year special attention has been given to the revision and issue of these maps. In the case of coalfields which have been extensively developed since the original survey was made, revision work has been heavy—in not a few cases the work was practically that of a new survey. The continuous progress of this work in recent years is gratifying and the detailed record of issues of new or revised maps, which is given in the Report of the Director, shows that publication has already gone far to provide the information required for guidance in the extension of Coal Mining.

The account of 'Inspections of Bores and Shafts' which the Director gives in his Report indicates the extent and value of this work of the Survey, now facilitated by the relevant provisions of the 'Mining Industry Act (1926).'

The accumulation of Records bearing on questions of Water Supply continues steadily. The publication of memoirs dealing with underground water supplies in many areas not only serves these areas directly, but helps to give publicity to the fact that for practically all populous areas much information is available for enquirers at the Offices of the Survey.

Geophysical Work

7. Good progress has been made during the year with the work of testing the Eötvös Gravity Torsion Balance on known areas in Britain. The second test, on a buried channel filled with Drift deposits in the Kelvin valley area, north-west of Glasgow, was

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completed; a third test in the neighbourhood of Portobello, about three miles east of Edinburgh, was put in hand and the work was practically finished by the end of the year. The object of this latter test was to investigate a well-marked fault or fracture line, bringing together rocks of different ages and differing only moderately in composition and in specific gravity. Full reports on these tests have been published or are in course of publication. As is mentioned in the Director's Report (see p. 35) it can be recorded that the Eötvös Balance has not failed to detect the geological structure which was previously known to exist in the ground examined. Under the circumstances in which the Balance has been employed it has proved to be a scientific instrument capable in skilled hands of yielding results of definite practical value as well as of theoretical interest.

We are glad to find that the experimental work carried out on the uses of the Eötvös Balance proved satisfactory and we trust that such applications of Physical Research may be utilised in geological investigations where the value of the possible results justifies the expenditure of time they involve.

Publication of Memoirs, etc.

8. The output of new memoirs during the year has again been large. Apart, too, from memoirs descriptive of one-inch sheets, other interesting volumes have appeared, viz.: two palaeontological monographs, three new county memoirs on Wells and Springs, and a Classified Catalogue of the Survey's collection of geological photographs and slides. This Catalogue enumerates a wide range of illustrations of geological phenomena and of typical surface features which are of much value for teaching purposes in schools of geology and geography. It is hoped that teachers and lecturers will find this list of considerable assistance to them in their work.

In the production of particular memoirs, as in other sections of its work, the Survey has continued to have the active co-operation of able geologists outside its own ranks, who have dealt with specific investigations in matters of which they have expert knowledge.

Co-operation on Soil Surveys

9. Officers of the Survey have continued to co-operate with experts on the investigation of methods by which the Survey could determine and record characteristics of soil that are of importance in Agriculture and Forestry. The soil map of the Kilmarnock Sheet, to which we referred in our last report, is now with the printer, and it will illustrate a method of recording and presenting information as to the nature of the soil in an extended area of varying soil types. The issue of this map and the accompanying memoir will be of value in enabling those who are interested in the uses of the soil to judge

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as to the service such maps can render. Apart from the preparation of special soil maps, the notes the geological surveyors, after their many consultations with soil experts, are now making upon maps of areas under survey should much increase the value of the work of the Survey to agriculturists.

Method of Reporting

10. During 1928 the *Summary of Progress* of the Geological Survey was for the first time published in two parts. Part I was given to the administrative side of the Survey's work and Part II was entirely devoted to papers on a variety of geological matters arising on the work in hand. It was felt that this arrangement would enable geological students to purchase at a reduced price that part of the Summary which was specially of scientific and of educational value, without having to pay at the same time for the section dealing with administrative matters. By separating Part II from Part I it was found possible to issue the collection of scientific papers at 2s. 6d. per copy, whereas the complete Report for the previous year was priced at 4s. 6d. per copy.

It is believed that this change will be appreciated by geological students and others for whom the cost of such works is a matter of importance.

Programme of Field Work

11. The programme of field-work for 1929 is :—

(*a*) primary mapping on the six-inch scale in the South-east of England (continue Reigate Sheet), in the Midlands district (finish Shrewsbury Sheet ; continue Dudley Sheet), and in Orkney and Shetland Islands. There will also be some primary six-inch revision of the Drift in the Saffron Walden Sheet ;

(*b*) revision of original six-inch mapping in the following coalfields and adjacent areas :—Lancashire, Yorkshire, Cumberland, Northumberland, Fifeshire, Ayrshire, Renfrewshire and Dumbartonshire (Sheet 30) ;

(*c*) investigation of underground water supplies ; verification of bore records ; examination of mineral resources ; and application of geophysical methods of surveying.

In concluding our Report for the year 1928 we desire to refer to the deaths of two very distinguished geologists, formerly members of the staff of the Geological Survey :—

(1) Sir Aubrey Strahan, who died on the 4th March, 1928, was Assistant to the Director of the Geological Survey in England

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from 1909 to 1914 and Director of the Survey and Museum from 1914 to July, 1920.

(2) Dr. John Horne, who died on the 30th May, 1928, was Assistant to the Director of the Geological Survey in Scotland from 1901 to 1911 and was a Member of this Board from 1920 to 1923.

The services which these officers gave are so well known in the geological world that no record of their achievements is required here. It is sufficient to say that their deaths mark a great loss to Geology.

F. G. OGILVIE,
Chairman.

5th April, 1929.

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SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY AND MUSEUM FOR 1928

1. REPORT OF THE DIRECTOR

FIELD work during the past year has been concentrated on the task of revising the maps of British coalfields, though, as will be seen from the list of new publications, other areas have been by no means neglected. In such work progress is necessarily slow as the information which must be collected is not only great in amount but is often difficult to obtain, being scattered in many hands. All the plans of old mines, shaft sections and bore records that can be traced must be reduced to standard form and minutely scrutinized before a satisfactory map can be constructed. The Mining Industry Act of 1926 by giving compulsory access to all plans of working mines is proving useful occasionally, though the Survey has seldom been refused information from mine owners and mine managers who understand the nature of our work. More difficulty is often experienced in a coalfield that has been worked out and abandoned than in areas where mining operations are being actively carried on. The Mines Department, however, has been compiling a list of the plans of abandoned mines, as a safeguard against accidents in working, and this list when completed will make it easier to trace the original sources of information. The value of a survey of coalfields depends entirely on the thoroughness with which the records have been investigated. Some areas where the Geological Survey is now at work were originally surveyed more than sixty years ago; and whole districts and large parts of coalfields have been opened, developed and worked out since that time. The old maps consequently have little value except as a general indication of the structure of the ground and the sequence of the more important strata. The revision of such a district amounts practically to a new survey and no effort is being spared to verify all the old information and to complete it by collecting all details of importance revealed by subsequent work.

In five districts of England field units have been engaged during the year in coalfield revision. Dr. Bernard Smith and his staff have taken in hand the maps of the Aspatria district, which is the eastward continuation of the Maryport and Workington field. Formerly there was no effective survey of this ground on the six-inch scale, though one-inch maps were published. This area forms an outlying part of the Whitehaven or Cumberland coalfield, and when it is finished the revision of that coalfield will have been completed and the maps will be in a satisfactory state for the first time. Meanwhile, the publication of the Whitehaven six-inch maps

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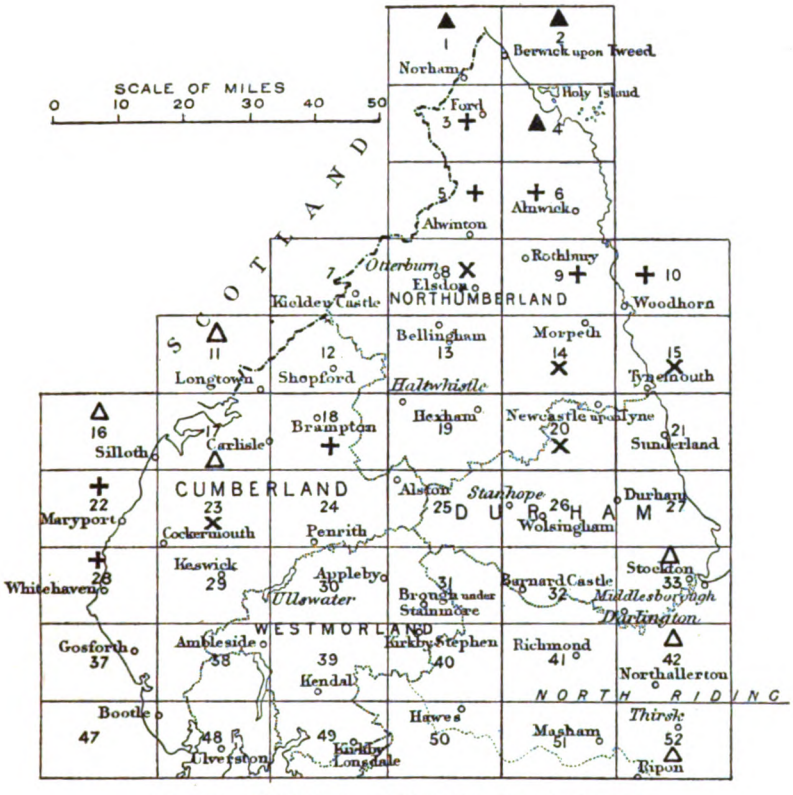

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▲	Published.	Revised, colour-printed, S. and D.
△	Published.	Revised, colour-printed, D.
+	Revised, not yet published.	
×	Under revision, 1919.	

FIG. 1.—*Index Map showing One-inch Geological Sheets of the North of England.*

is going on and the one-inch maps of Whitehaven (Sheet 28) and Maryport (Sheet 22) are in the press.

In Lancashire Dr. Wright and his staff, having finished the revision of the Rochdale and Manchester Sheets (76 and 85), are actively engaged in the Wigan Sheet (84). The structure is complicated by faulting, and much of the mining information is old and difficult to collect, but steady progress is being made and the field work may be finished next season. In this district there is little to be learned from surface outcrops but the underground information is very heavy, and the old six-inch maps, though excellent for their time, are no longer of value for practical purposes.

In the West Riding of Yorkshire Mr. Bromehead and his staff have completed the re-survey of the Glossop Sheet (86) and the

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six-inch maps are now being reduced to standard form for engraving. This is the second Sheet which has been revised by this unit, as the Huddersfield Sheet (77), completed two years ago, is now published

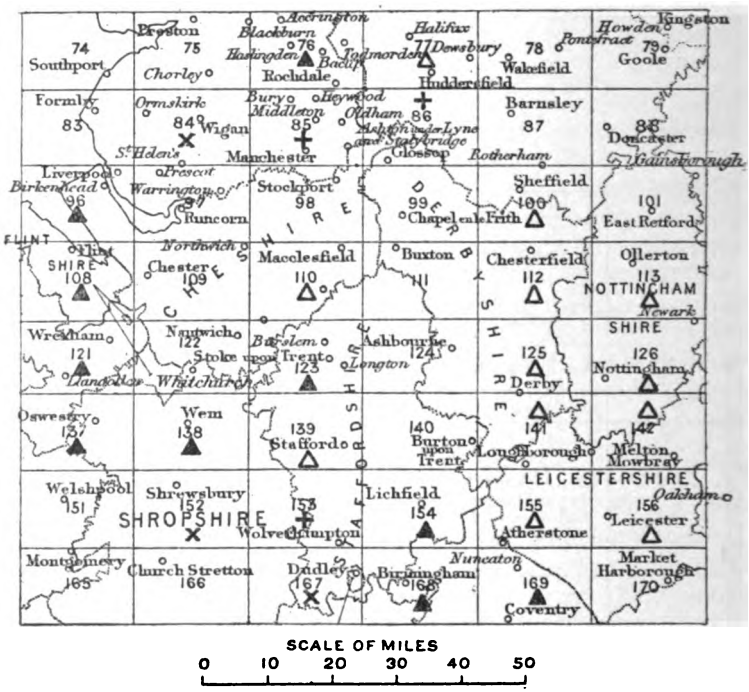

FIG. 2.—*Index map showing One-inch Geological Sheets of English Midlands.*

and the memoir describing it is almost ready to go to press. A revised edition of the memoir on the Concealed Coalfield of Yorkshire was also published two years ago. This indicates that steady progress is being made in providing reliable information on the structure and resources of this most important area of Coal Measures.

The progress of the Northumberland unit under Mr. Carruthers has been hampered to some extent by the death of Mr. Maden and the illness of another member of the staff. Consequently only one geologist has been employed in the field during a considerable part of the year. This group has undertaken first the revision of the limestone country from Berwick southwards, as it contains a

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group of coals, formerly worked in many places but now almost unwrought, about which the available information was previously deficient. Eight Sheets or parts of Sheets (1, 2, 3, 4, 5, 6, 9, 10) have been revised and three are published (1, 2 and 4); one more (Sheet 6, Alnwick) is in the press, and two are preparing for the engraver. At present it is more important to hasten the publication of the work that has been done than to press forward the field work. The Northumberland and Durham coalfield so far as composed of Coal Measures rocks has as yet only been touched in a few places.

In the West Midlands of England the unit formerly under Mr. Cantrill has continued its advance under Mr. C. H. Dinham, who has been transferred from Scotland. Its operations during the year were confined to the Shrewsbury Sheet (152) which contains the Shrewsbury, Leebotwood and part of the Coalbrookdale coalfields. In many respects this is a most interesting Sheet, as it embraces representatives of various formations ranging from the Pre-Cambrian to the Trias. Some interesting discoveries have been made in the older rocks by Mr. Pocock, for an account of which reference is made to Mr. Dinham's report. The revision of this Sheet will be completed early in 1929 and the Dudley Sheet (167) will be taken in hand. The revision of the Midlands coalfields will then have been practically finished.

In Scotland comparatively little field work has been done in the coalfields during the past year. The Ayrshire unit under Mr. Bailey re-surveyed a small outlying area of that coalfield around New Cumnock. It lies mostly beyond the boundaries of Sheet 14 (Ayr) but is connected geologically with the Coal Measures within that Sheet and a description of that ground is to be included in the Memoir on the Economic Geology of the Ayrshire Coalfields (Part IV). Mr. Ross, the only member of the Lanarkshire unit who was engaged in coalfield survey, has finished the six-inch mapping of the Douglas coalfield, an outlying area which is very important and of highly complex structure. In Fife Mr. Knox was the only geologist to do field work, and after his return from a three months stay in the Orkneys he carried on the revision of the coalfield about Leslie. This is the only important Scottish coalfield left to be revised and when it is finished the work remaining will be confined to small areas like Sanquhar and Campbeltown. The six-inch coalfield maps of Scotland are issuing steadily from the press, but before the new one-inch maps of Clackmannan, Fife and Renfrewshire can be published it will be necessary to make an examination of the pre-Carboniferous areas that occupy a large part of these Sheets.

Meanwhile, the production of the six-inch and one-inch maps and of the memoirs descriptive of the coalfields is being pushed forward. In Scotland there are certain conditions that render this work slow and laborious. One of these is the great abundance of bore-records; in some quarter-sheets of six square miles of coalfield there are over two hundred bores. This arises again from the broken

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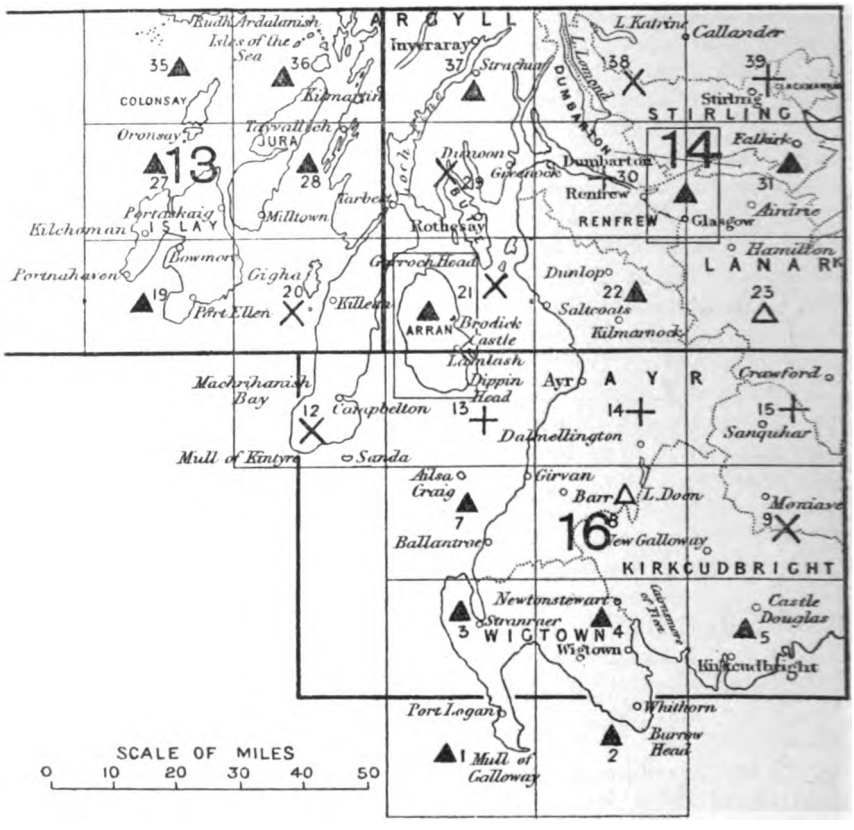

▲ Published, colour-printed.
△ Published, hand-coloured. Revised, colour-printed edition in the press.
+ Published, hand-coloured. Revision in progress.
X Published, hand-coloured.

FIG. 3.—*Index map showing One-inch Geological Sheets of the South-west of Scotland.*

and faulted nature of the rocks, which renders mining operations hazardous and uncertain unless the ground is thoroughly proved by boring. Another important factor is the large size of the Scottish one-inch sheets, which cover nearly double the area of the corresponding sheets in England. The wide extent of igneous rocks requiring careful petrological study involves additional labour ; for example, about one-half of the Kilmarnock Sheet (22) recently published is occupied by lavas and intrusions. Until the whole of this work is done it is not possible to produce a geological map showing the structure and relations of the rocks in a really satisfactory manner, likely to stand the test of time and meet the demands of industrial progress.

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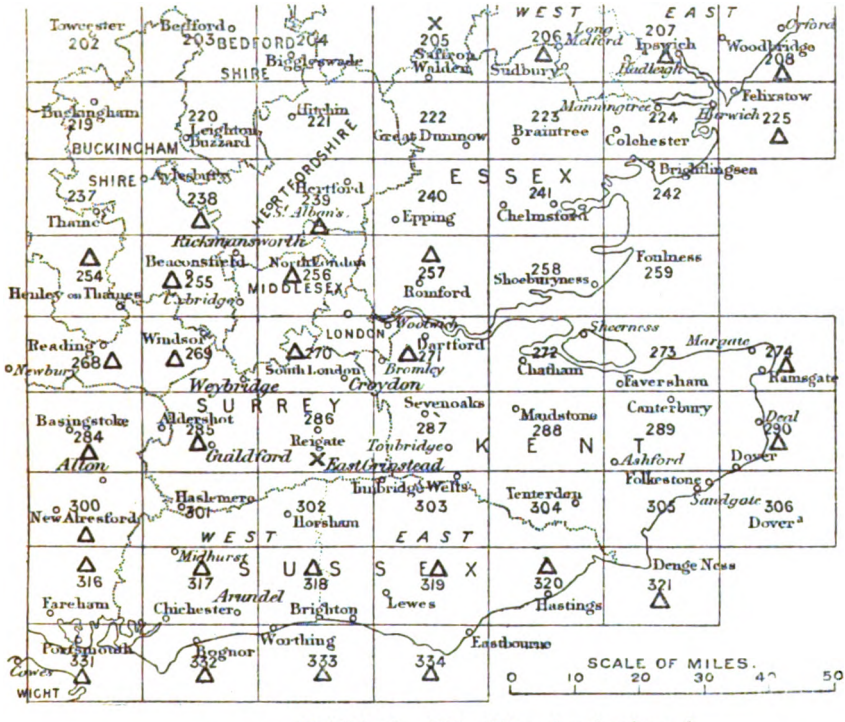
In areas which are not productive or potential coalfields a large extent of ground has been revised during the past year. With the completion of the Aldershot Sheet (285) during the previous year the adjacent Reigate Sheet (286) was begun and Mr. Edmunds



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△	Published. Revised, colour-printed, Drift.
×	Under revision, 1929.

FIG. 4.—*Index map showing One-inch Geological Sheets of the South-east of England.*

and Mr. Dines have been employed there during most of the field season; for a short time towards the end of the year they had the assistance of Dr. Stubblefield, who joined the staff in October. Mr. Dines has also revised certain drift formations in the Moreton-in-Marsh Sheet (217) for which a memoir has been written by Mr. Linsdall Richardson. Mr. Osborne White is preparing a memoir on the Saffron Walden Sheet (205), and his work will be supplemented by some necessary revision during the present year. A new edition of the Torquay Memoir and one-inch Sheet (350) being rendered necessary by the exhaustion of the current edition, Mr. Lloyd has spent most of the year in that district gathering materials for a

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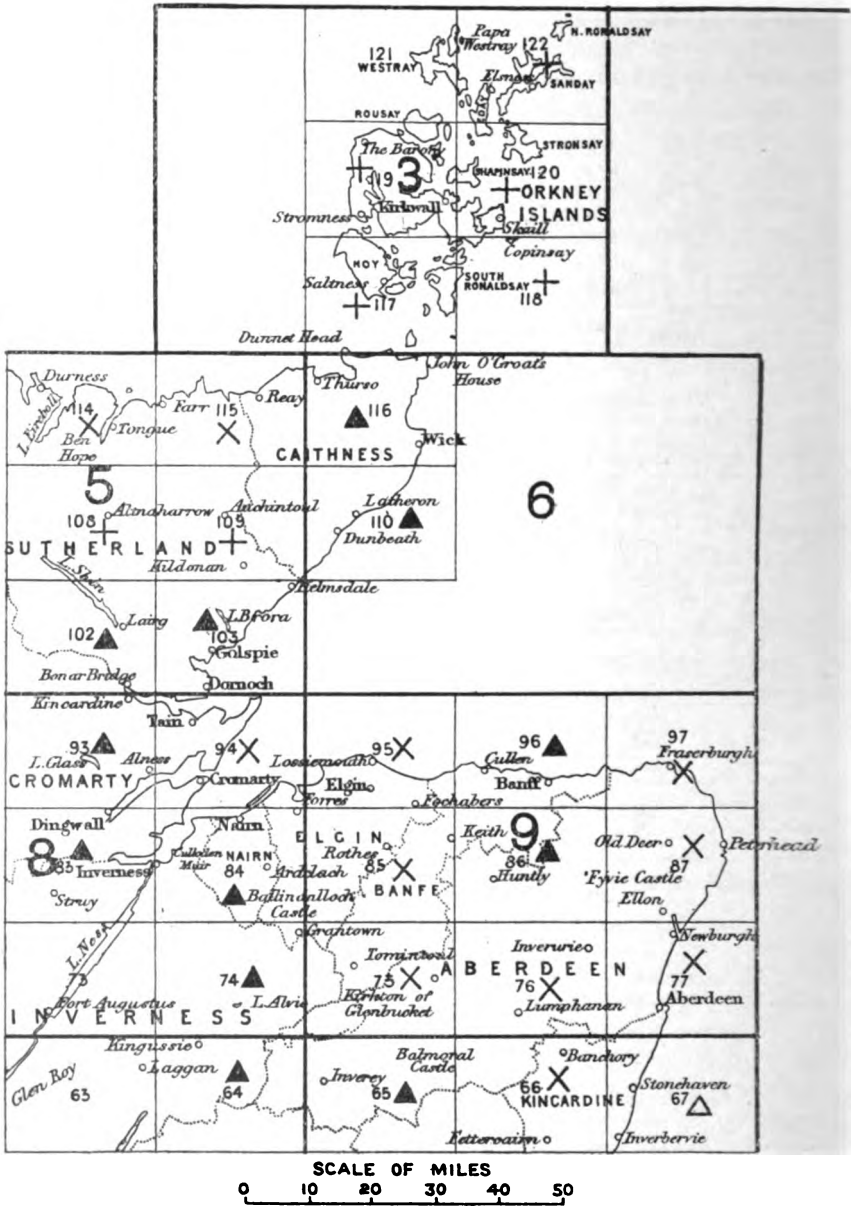

SCALE OF MILES
0 10 20 30 40 50

▲ Published, colour-printed.
△ Published, hand-coloured. Revised, colour-printed edition in the press.
\+ In preparation.
✕ Published, hand-coloured.
Maps without symbol unsurveyed.

FIG. 5.—*Index map showing One-inch Geological Sheets of the North-east of Scotland.*

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revision. Two other Sheets of which new editions are required are the Land's End (351-8) and Lizard Sheets (359) which are occupying the attention of Mr. Dewey and the Director.

The only mapping of ground not previously surveyed was done in the Orkney Islands. Mr. G. V. Wilson, recently appointed District Geologist, has now charge of that area, and had the assistance of two or three geologists for part of the season. The survey of nearly two-thirds of the county has been completed. It is expected that unless unforeseen circumstances delay progress the mapping of the Orkneys will be finished by the close of 1929.

Field work will also be undertaken in Shetland where as many Scottish geologists as it is possible to set free from coalfield work will be sent early in summer. They may have the assistance of a few members of the English staff for a short time as the field season in these islands is necessarily very short. When the results of the revision of the Scottish coalfields have been more fully published it will be possible to carry on the primary Highland mapping with more activity and to resume work in some districts where it was suspended for a time in order to accelerate the much needed resurvey of districts of economic importance.

It may be noted also that the staff of the late Professor Berry in the West of Scotland Agricultural College have continued their investigation of the distribution of soil-types in the Ayrshire province.

PUBLICATIONS

MAPS, VERTICAL SECTIONS, ETC.

Of the quarter-inch map of England and Wales one Sheet has appeared in a new edition. This Sheet (11) represents a large area, of which Derby is the centre, extending on the west to Crewe and on the east to Lincoln. It is the first quarter-inch Sheet to be printed with the new series of colours of which a complete scheme was drawn up last year. The objects aimed at in the revised scheme are greater simplicity in printing with more contrast in the colours. These small scale maps are often used as wall-diagrams for teaching classes and a vigorous colouring is desirable for this purpose. This map is on the whole successful, and the colours are well balanced, though some of the darker tints are not so transparent as in the previous edition. The alterations in the geology of this Sheet are not of great importance, though all the necessary changes have been introduced to represent the present state of our knowledge of the district.

Several other Sheets of this map are nearly sold out and new editions will be put in hand as soon as required. It is advisable to keep the old edition on sale for a time to enable purchasers to

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make up complete maps of large areas for which matched copies are often in demand.

The number of maps published during the year is considerable, though not so large as in the previous year. An exceptionally large number of English one-inch maps has passed through the press. The Huddersfield Sheet (77) is the first of the revision of the West Yorkshire Coalfield and is a sister map to the Rochdale Sheet (76) which was published last year. In this case, however, only one edition was necessary, as the superficial deposits in the Huddersfield district do not cover an extensive area. Another important coalfield sheet is Oswestry (137) which has been issued both in solid and drift editions. This Sheet completes the one-inch series of the North Wales coalfields, and the whole of the coalfields of Wales are now available in colour-printed maps of the new one-inch series. The corresponding memoir was nearly ready for sale at the close of the year. The revised six-inch maps of the North Wales coalfields have all been published.

The other English one-inch sheets in the subjoined list, Sudbury (206), Woodbridge (208), Felixstowe (225), Ramsgate (274), Dover (290), Hastings (320), Dungeness (321) and Aldershot (285), have all received some revision to bring them up to date, but only the Aldershot Sheet is completely re-surveyed on the scale of six inches to one mile. The publication of these new geological maps of the South and East of England is a matter of considerable importance as these districts are populous, and their agricultural industries are rich and varied. Many requests for information about these counties are received from people in search of water supply, or for suitable residential districts, and the new maps are much in demand. With the completion of the re-survey of London and its environs attention has been directed to the principal residential districts and especially to the coast resorts and it is hoped to make steady progress with the preparation of new maps of the south-eastern counties.

The Windsor map, which was published in the New Series in 1920, has recently been sold out and a new edition is in the press in which certain alterations are being made in the colour-printing, while the geology of the map is essentially unchanged.

The most important Scottish map to be published during the year is the Kilmarnock Sheet (22) which was issued in both solid and drift editions. This sheet is large and complex and the varied geology necessitated a very elaborate series of colours. A further edition is in the press showing the physical types of soil in the Kilmarnock area. These three maps taken together will form the most complete representation of any district that the Geological Survey has yet published.

As the Edinburgh Sheet (32) issued in 1910 was nearly sold out and the old edition was not completely satisfactory it was decided to prepare at once a drift edition showing accurately all the

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superficial deposits, which cover more than nine-tenths of the region. That map has been published and meanwhile the stocks of the old map have been exhausted. A solid edition of that Sheet is now engraving and will be issued in 1929. In the former edition the attempt to represent both solid and drift on a single map resulted in obscurity owing to excessive detail, and the new maps are of the same type as those of Kilmarnock (22) which are believed to be better in all respects. The new solid map is not based on a complete re-survey, but will differ from the previous edition in several respects, as all the information that has been obtained since the previous edition was issued has been incorporated. In the oil-shale fields, for example, there are important changes owing to the additional particulars collected from the mining companies during the preparation of the third edition of the memoir on the Oil-Shales of the Lothians published in 1927.

Of the six-inch maps which are intended to show the detailed geology of the coalfields a very satisfactory number has passed through the press during the year. Ten of these are from Cumberland (principally in the Whitehaven and Maryport districts), and cover the most difficult and most productive parts of that field. Seven sheets are from the Manchester district of Lancashire; eight are from Northumberland; seven are from the Huddersfield and Dewsbury district in Yorkshire; six are from Shropshire. Four maps of the South Wales coalfield have also been published and indicate the continuation of a revision of that field which makes the third survey of South Wales.

Among the Scottish six-inch maps published during the year there are eleven sheets of Ayrshire which carry the publication of that coalfield well forward towards completion. The other eight maps represent parts of Clackmannan, Fife and Stirling. A special map on the scale of four miles to one inch, showing the six-inch quarter sheets of the revised coalfield survey, has been prepared to serve as an index map for office use. As such a map will undoubtedly be of interest for reference it is expected that it will ultimately be published along with a list of the new six-inch maps of Scottish coalfields when further progress has been made with the publication of that series.

Three sheets of vertical sections of strata were published during the year and four others are in the press. Requests were received from South Wales for certain vertical sections of shafts and borings in that field which were no longer on sale, and as they are still of interest they received a few corrections and additions and were sent to be reprinted. A new plate of sections from the Abergavenny district has also been drawn up by Dr. Robertson, based on information collected during his recent revision of that sheet in connexion with the second edition of the Sheet memoir which was issued in 1927. This will be printed in a simple colour scheme, like several other sheets of vertical sections recently issued by the Geological

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Survey. It is found that these coloured sheets are more rapidly engraved and printed and have certain other advantages over the old sheets which were uncoloured but had the stratal characters represented by ornament in black and white. These latter involved a great expenditure of time in drawing the ornament. In Scotland also colour-printed sheets of vertical sections have now found favour. One has already been published for North Ayrshire and another is in hand for Central Ayrshire. The single Scottish sheet of Vertical Sections published during the past year is the last of a series designed to illustrate the new six-inch maps of the Central Coalfield and the set of economic memoirs relating to that field.

Memoirs

As will be seen from the list of published memoirs, there has been great activity on the part of the English Survey in this connexion during the past year. Thirteen volumes have been sent out, including the *Summary of Progress* and a revised edition of the List of Memoirs, Maps and Sections. These include two important contributions to British palaeontology, which, though written by experts who are not now on our regular staff, are based on the collections of the Survey in London and in Edinburgh. Very careful search of all sources of information has been made, however, in preparing these monographs, and the authors are much indebted to the officers of the British Museum, Royal Scottish Museum, Sedgwick Museum and other curators of British collections of fossils for granting full access to the materials in their custody and for many other services of a valuable kind.

Three memoirs on the Water Supply of English counties have been published during the year. Two of these have been compiled by Mr. L. Richardson and the third by Mr. Edmunds. These memoirs involve much labour in collecting and checking the records, and though they appeal to only a limited public they serve a very useful purpose and are much appreciated by well borers, medical officers of health and water engineers. In addition to this they contain a very large amount of detailed and accurate information regarding the strata of the counties which they describe, and the work spent in bringing together the information is fully justified by the importance of the subject. Four other water supply memoirs are in the press or in preparation and will be published when complete, viz., Derbyshire, Worcestershire, Gloucestershire and Leicestershire. For three of these we are indebted to the assistance of Mr. Richardson, who has made use of all the collected information in the Survey offices and has added much valuable material to it by strenuous enquiry from all available sources. Most of the recent memoirs of this series have the principal borings numbered and corresponding numbers are placed on a series of reference maps which are open for consultation by the public in the Survey library

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and give the exact site of the boring when that is accurately known. It is a matter of considerable importance to know the exact position of a boring, and this is usually not difficult to ascertain when the boring is in use and yields large quantities of water. But some of the older borings which were not successful or were abandoned can no longer be located; in such cases the information may be of interest to a geologist, and especially if the country is traversed by faults may give very significant indications as to the distribution of underground water resources and the best situations in which to make search for new supplies.

Three memoirs on the geology of the South and East of England have also made their appearance, one by Professor Boswell, of Liverpool University, and two by Mr. H. J. Osborne White. Along with these memoirs new colour-printed versions of the corresponding one-inch maps have been issued with such alterations as were considered desirable to bring them up to date, but a complete re-survey of the ground on the six-inch scale was not undertaken because it seemed unnecessary.

Both the Woodbridge and the Hastings district are classic geological country and these short and readable descriptions give the most recent views on the structure and problems of these well-known areas with a summary of the literature and a description of the new colour-printed map.

Two coalfield memoirs dealing with the West Midlands and an adjacent portion of North Wales are included in the list of the year's publications. These memoirs are full of detail regarding the geology of the coalfields, and have taken much labour in compiling. Another memoir of this series, on the Oswestry Sheet (137) is in the press, and this will complete the description of the coalfields of North Wales, bringing to an end a piece of work that was interrupted by the War and has suffered considerable delay owing to many unforeseen circumstances. Mr. T. C. Cantrill, who has now retired from the staff, was fortunately able to complete the editorial work, and make the manuscripts ready for the press before his retirement.

One memoir on Scottish geology was published during the year, an account of the Island of Arran by Dr. G. W. Tyrrell, of Glasgow University. No complete account of this most interesting island had previously been issued by the Geological Survey, though a volume on North Arran by W. Gunn and Dr. A. Harker was published in 1903 and has been out of print for a year or two. Dr. Tyrrell's services in this connexion were most valuable, for he had an excellent knowledge of the geology and petrology of Arran, and he made full use of the original maps of Gunn and the notes which that geologist had left in preparation for a memoir on the southern half of the island. The new Arran memoir made an opportune appearance and was welcomed by the geologists who took part in the meeting of the British Association in Glasgow in September. It furnishes a complete description of the area included in the special

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colour-printed map of Arran which was based on the survey by William Gunn. For the first time a complete account of the geology of Arran is now at the disposal of visitors to the island and to students of volcanic rocks in general. The Tertiary volcanic centres of Skye, Rum, Mull and Arran are all described in memoirs of the Geological Survey, and when the forthcoming volume on Ardnamurchan is printed no department of British geology will have been more fully discussed and illustrated.

Special Reports on Mineral Resources

No addition to this series has been made during the past year. Thirty volumes have now been published since 1915, and several of them have passed through three editions. More than one of these volumes is now nearly sold out and new editions will have to be prepared when a sufficient amount of fresh information has been collected to justify that course. The great activity that marked the exploitation of British mineral deposits towards the close of the War and for a time thereafter has considerably diminished, and the demands for information are not so insistent as they were. It is mostly from new mining developments that useful information can be obtained, and though efforts are made to keep in touch with the advance of exploration and mining, the growth of knowledge is slow when the industry is inactive. At present this series may be regarded as fairly comprehensive and sufficiently up-to-date to fulfil its purpose. One new volume is in the press—an account of English Ball Clays by Dr. A. Scott, of the Potteries Laboratory. This will form a useful companion volume to Mr. J. Allen Howe's memoir on Kaolin and China Clay. Both series of deposits are the foundation of important British industries, and the memoirs in question furnish adequate descriptions of the mineralogy, geology, distribution, origin and special characters of the British china-clays and pottery clays with numerous chemical analyses prepared specially in the Survey laboratory or by expert analysts.

In connection with the series of Economic Memoirs and Special Reports on Mineral Resources the preparation of a handbook on Attrition Tests of British Road-stones may here be mentioned. The Geological Survey has a very fine collection of British road-stones, amounting to over 1,200 in number, all of which have been sliced and examined microscopically and tested by various methods as regards durability, specific gravity, and other physical characters. This collection was initiated by Mr. E. J. Lovegrove in 1903 when he was Borough Engineer of Hornsey and the results of the first 213 were published in 1906, accompanied by petrographical descriptions by Mr. Howe and Sir John Flett. Subsequently Mr. Lovegrove carried on the work and his complete series of tests number 468. He has presented all the specimens to the Museum of Practical Geology, where a representative set of rocks with tables, maps and

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photographs has been exhibited for several years. This exhibit has now been removed to a more convenient place in the Museum and re-arranged by Miss E. M. Guppy, who has assisted in the preparation of a new handbook to the Lovegrove collection which is now in the press.

When in 1911 the Road Board took up the testing of road-stones at the National Physical Laboratory, Teddington, Mr. Lovegrove discontinued his series of tests. Road-stone testing as practised at Teddington is not conducted by the same methods as those invented and used by Mr. Lovegrove, and consequently the numerical results cannot be strictly compared. The Lovegrove Collection is complete in itself and represents the first practical experiments in this branch of stone investigation in Great Britain. As the descriptive handbook, published in 1906, is sold out and many enquiries had been received for a new and revised edition it is felt that this little book will serve a useful purpose.

Water Supply Memoirs

As is indicated on page 29 there have been several Water Supply Memoirs published during the year, and a good deal of work has also been done in the preparation of memoirs on four other counties—Derbyshire, Worcestershire, Gloucestershire and Leicestershire. These four memoirs will probably go to press in 1929. The new edition of London Wells which has been in preparation for some time has not yet gone to press as the current edition is not quite sold out. Very numerous enquiries are being received about the superficial formations of the London district, owing partly, no doubt, to the large amount of building that is going on, and new information flows in steadily from many sources regarding excavations, borings and wells. The economic importance of this is obvious, and the Geological Survey is much indebted to builders, architects, well-sinkers and borers for the readiness with which they supply particulars. The inspectors of the London County Council have in all cases been most helpful and neglect no opportunity to record observations on the formations underlying London.

Many enquiries are also received from people in search of residences in and around London who wish to know the conditions of soil and subsoil in the various suburbs and surrounding districts in respect not only of water supply but also of amenity and freedom from waterlogged conditions.

The series of water supply memoirs regarding the south-east of England is now reasonably complete, as will be seen from the map on page 22. These districts were taken first as they are the most dependent on underground sources for their water supplies. In counties where the Chalk and the Greensand are well developed the problem of obtaining supplies is often easily solved by a knowledge of the geological conditions. The memoirs more recently published

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FIG. 6.—*Index Map showing areas described in Water-supply Memoirs.*

1, 2. Bedfordshire and Northamptonshire.
3. Berkshire.
4, 5. Buckinghamshire and Hertfordshire.
6, 7, 8. Cambridgeshire, Huntingdonshire and Rutland.
9. Dorset.
10. Essex.
11. Hampshire.
12. Kent.
13. Lincolnshire.
14. London Wells.
15. Norfolk.
16. Nottinghamshire.
17. Oxfordshire.
18. Somerset.
19. Suffolk.
20. Surrey.
21. Sussex.
22. Warwickshire.
23. Wiltshire.
24. Yorkshire, East Riding, etc.
25. Derbyshire. } In
26. Gloucestershire. } preparation.
27. Leicestershire. } preparation.
28. Worcestershire. } preparation.

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have referred to Midland and Western counties where the geological structure is more complex and the problems are often more difficult of solution. The series of twenty-four memoirs published and in preparation on British water supplies from underground sources are standard reference works to all who are interested in questions of this kind, and represent a valuable contribution to British hydrography. These memoirs form, however, only a part of the information which the Survey has collected as there is a great mass of unprinted material in the records contained in the Survey offices. Enquiries are received in great numbers and all the relative data in our possession are freely placed at the service of the engineers and others who desire to obtain such information. In turn we receive from all the principal well-sinkers and borers in Britain the fullest possible information regarding new wells and bores, and this department of the Survey's work, though little known to the general public, is one that serves a most useful purpose and could be carried on by no other agency so efficiently and with so little expenditure.

The following maps, vertical sections and memoirs were published in 1928 :—

I.—Maps

English and Welsh Maps published in 1928

¼ inch to 1 mile :—

Sheet 11.—Derby, Lincoln, Sheffield, Stafford. (*Solid Edition, Revised.*)

1 inch to 1 mile :—

Sheet 77.—Huddersfield (*Drift Edition*). Originally published on Old Series map. Re-surveyed by D. A. Wray, J. V. Stephens, Wilfrid Edwards and W. Lloyd ; C. E. N. Bromehead, District Geologist.

Sheet 137.—Oswestry (*Solid and Drift Editions*). Original survey on one-inch scale. Re-surveyed by C. B. Wedd, B. Smith, L. J. Wills, W. B. R. King and D. A. Wray ; G. W. Lamplugh and T. C. Cantrill, District Geologists.

Sheet 206.—Sudbury (*Drift Edition*). Original survey by F. J. Bennett, J. H. Blake, W. H. Dalton, W. H. Penning and W. Whitaker. Part re-surveyed by P. G. H. Boswell. Transferred to the New Series map with minor corrections.

Sheet 208.—Woodbridge (*Drift Edition*). Original survey by W. Whitaker and W. H. Dalton. Transferred to the New Series map.

Sheet 225.—Felixstowe (*Drift Edition*). Original survey by W. Whitaker and W. H. Dalton. Transferred to the New Series map.

Sheet 274.—Ramsgate (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map with additions by F. H. Edmunds.

Sheet 285.—Aldershot (*Drift Edition*). Original survey on one-inch scale. Re-surveyed by C. E. N. Bromehead, H. G. Dines and F. H. Edmunds ; H. Dewey, District Geologist.

Sheet 290.—Dover (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map with additions by H. G. Dines and F. H. Edmunds.

Sheet 320.—Hastings (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map.

Sheet 321.—Dungeness (*Drift Edition*). Original survey on one-inch scale. Transferred to the New Series map.

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6 inches to 1 mile (coalfield maps) :—

Cumberland, 19 N.W.—Hartleyburn Common. Original survey by D. Burns. Re-surveyed by F. M. Trotter ; B. Smith, District Geologist.

Cumberland, 44 N.E.—Maryport. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 44 S.E.—Flimby. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 45 N.W.—Ellenborough. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 45 S.W.—Broughton Moor. Original survey by R. Russell. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 54 N.W.—Broughton. Original survey by R. Russell. Carboniferous Rocks revised by J. G. Goodchild. Re-surveyed by T. Eastwood ; B. Smith, District Geologist.

Cumberland, 54 S.W.—Little Clifton. Original survey by R. Russell. Millstone Grit and older rocks revised by J. G. Goodchild. Re-surveyed by E. E. L. Dixon ; B. Smith, District Geologist.

Cumberland, 62 N.W.—Branthwaite. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon ; B. Smith, District Geologist.

Cumberland, 62 S.W.—Kidburngill. Original survey by R. Russell. Revised by A. Strahan. Re-surveyed by E. E. L. Dixon ; B. Smith, District Geologist.

Cumberland, 72 N.E.—Egremont. Original survey by W. T. Aveline and R. Russell. Part revised by A. Strahan. Re-surveyed by B. Smith, District Geologist.

Glamorganshire, 12 N.E. (Mon. 16 N.E.).—Pontlottyn (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Lancashire, 87 N.W.—Bradshaw. Original survey by E. Hull. Re-surveyed by W. B. Wright and R. C. B. Jones ; W. B. Wright, District Geologist.

Lancashire, 87 N.E.—Tottington. Original survey by E. Hull. Re-surveyed by W. B. Wright and R. L. Sherlock ; W. B. Wright, District Geologist.

Lancashire, 87 S.W.—Bolton. Original survey by E. Hull. Re-surveyed by R. C. B. Jones ; W. B. Wright, District Geologist.

Lancashire, 88 N.W.—Birtle. Original survey by E. Hull. Re-surveyed by L. H. Tonks ; W. B. Wright, District Geologist.

Lancashire, 88 S.W.—Bury. Original survey by E. Hull. Re-surveyed by L. H. Tonks ; W. B. Wright, District Geologist.

Lancashire, 95 N.W.—Farnworth. Original survey by E. Hull. Re-surveyed by R. C. B. Jones ; W. B. Wright, District Geologist.

Lancashire, 96 N.W.—Whitefield. Original survey by E. Hull. Re-surveyed by L. H. Tonks ; W. B. Wright, District Geologist.

Monmouthshire, 17 N.E.—Blaenau-Gwent (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 17 S.E.—Aberbeeg (*Revised Edition*). Original survey by W. Gibson. Revised by T. Robertson.

Monmouthshire, 18 S.E.—Pontypool (*Revised Edition*). Original survey by A. Strahan. Revised by T. Robertson.

Northumberland, N. 10 N.E.—Ford. Original survey by W. Gunn. Revised by R. G. Carruthers and F. Marsden ; R. G. Carruthers, District Geologist.

Northumberland, N. 11 N.W.—Bar Moor. Original survey by W. Gunn. Revised by R. G. Carruthers, C. H. Dinham and F. Marsden ; R. G. Carruthers, District Geologist.

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Northumberland, N. 34 N.E.—Abberwick. Original survey by W. Topley. Revised by R. G. Carruthers, W. Anderson and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 34 S.E.—Edlingham. Original survey by W. Topley. Revised by W. Anderson and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 35 S.E.—High Buston. Original survey by W. Topley. Revised by R. G. Carruthers, C. H. Dinham and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 43 N.W.—Newton-on-the-Moor. Original survey by W. Gunn and W. Topley. Revised by C. H. Dinham, A. Fowler and J. Maden; R. G. Carruthers, District Geologist.

Northumberland, N. 43 S.E.—Acklington. Original survey by W. Topley. Revised by A. Fowler; R. G. Carruthers, District Geologist.

Northumberland, N. 49 S.E.—Blagdonburn. Original survey by W. Topley. Revised by J. Maden; R. G. Carruthers, District Geologist.

Shropshire, 12 N.W.—Selattyn. Surveyed by L. J. Wills and C. B. Wedd; G. W. Lamplugh, District Geologist.

Shropshire, 12 N.E.—New Marton. Surveyed by L. J. Wills and C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 12 S.W.—Oswestry. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 12 S.E.—Whittington. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 18 N.E.—Llansilin. Surveyed by B. Smith and C. B. Wedd; T. C. Cantrill, District Geologist.

Shropshire, 19 S.W.—Llynclys. Surveyed by C. B. Wedd; T. C. Cantrill, District Geologist.

Yorkshire, 215 N.E.—Denholme. Original survey by J. R. Dakyns, J. C. Ward, C. Fox-Strangways and W. H. Dalton. Re-surveyed by J. V. Stephens; C. N. Bromehead, District Geologist.

Yorkshire, 215 S.E.—Mixenden. Original survey by J. R. Dakyns, J. C. Ward, C. Fox-Strangways and W. H. Dalton. Re-surveyed by J. V. Stephens; C. N. Bromehead, District Geologist.

Yorkshire, 246 S.E.—Huddersfield. Original survey by J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Yorkshire, 247 N.W.—Mirfield. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 247 N.E.—Dewsbury. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by C. N. Bromehead, District Geologist.

Yorkshire, 260 N.E.—Almondbury. Original survey by J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Yorkshire, 261 N.W.—Kirkburton. Original survey by A. H. Green, J. C. Ward and R. Russell. Re-surveyed by D. A. Wray; C. N. Bromehead, District Geologist.

Scottish maps published in 1928

1 inch to 1 mile :—

Sheet 22.—Kilmarnock (*Solid and Drift Editions*). Original survey by A. Geikie and J. Geikie. Revised by C. T. Clough, E. B. Bailey, E. M. Anderson, R. G. Carruthers, C. H. Dinham, J. E. Richey, G. V. Wilson, G. A. Burnett, V. A. Eyles, J. B. Simpson, A. G. MacGregor and J. Phemister; C. T. Clough and E. B. Bailey, District Geologists.

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Sheet 32.—Edinburgh (*Drift Edition*). Original survey by A. Geikie and H. H. Howell. Revised by Sir A. Geikie, H. H. Howell, B. N. Peach, J. S. Grant-Wilson and H. M. Cadell. Further revision by B. N. Peach, C. T. Clough, L. W. Hinxman, J. S. Grant-Wilson, W. Gibson, E. H. Cunningham-Craig, C. B. Crampton, H. B. Muff, E. B. Bailey, E. M. Anderson and G. W. Grabham. (*New Colour-printed edition.*)

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 26 S.E.—Glenbuck. Original survey by B. N. Peach. Revised by E. M. Anderson, G. V. Wilson and G. Ross ; M. Macgregor and J. E. Richey, District Geologists.

Ayrshire, 30 N.E.—Burnfoot Moor. Original survey by B. N. Peach. Revised by G. V. Wilson ; M. Macgregor, District Geologist.

Ayrshire, 31 N.W.—Muirkirk. Original survey by B. N. Peach. Revised by G. V. Wilson ; M. Macgregor, District Geologist.

Ayrshire, 34 S.W.—Coylton. Original survey by A. Geikie. Revised by V. A. Eyles ; E. B. Bailey, District Geologist.

Ayrshire, 40 N.W.—Craigs of Kyle. Original survey by J. Geikie. Revised by V. A. Eyles ; E. B. Bailey, District Geologist.

Ayrshire, 40 S.W.—Patna (N. of). Original survey by J. Geikie. Revised by A. G. Macgregor ; E. B. Bailey, District Geologist.

Ayrshire, 40 S.E.—Rankinston. Original survey by J. Geikie. Revised by J. B. Simpson ; E. B. Bailey, District Geologist.

Ayrshire, 41 N.W.—Knockdunder. Original survey by J. Geikie. Revised by J. B. Simpson ; E. B. Bailey, District Geologist.

Ayrshire, 46 N.W.—Patna, Waterside. Original survey by J. Geikie. Revised by A. G. Macgregor ; E. B. Bailey, District Geologist.

Ayrshire, 50 N.E.—Wallacetown. Original survey by A. Geikie. Ordovician and Silurian revised by B. N. Peach and J. Horne. Post-Silurian by J. E. Richey ; E. B. Bailey, District Geologist.

Ayrshire, 50 S.E.—New Dailly. Original survey by A. Geikie. Ordovician and Silurian revised by B. N. Peach and J. Horne. Post-Silurian by J. E. Richey ; E. B. Bailey, District Geologist.

Clackmannanshire, 139 N.W.—Blackgrange. Original survey by B. N. Peach. Revised by C. H. Dinham and H. H. Read ; C. H. Dinham, District Geologist.

Clackmannanshire, 139 S.E.—Mouth of Black Devon, Dunmore. Original survey by B. N. Peach. Revised by C. H. Dinham, H. H. Head and D. Haldane ; C. H. Dinham, District Geologist.

Fifeshire, 34 S.E.—Cowdenbeath. Original survey by H. H. Howell and A. Geikie. Revised by J. K. Allan ; C. H. Dinham, District Geologist.

Fifeshire, 37 N.W.—Kincardine-on-Forth. Original survey by B. N. Peach. Revised by C. B. Crampton, C. H. Dinham and D. Haldane ; C. H. Dinham, District Geologist.

Fifeshire (40 N.E. and 41 N.W.)—Kinghorn. Original survey by H. H. Howell and A. Geikie. Revised by J. Knox ; C. H. Dinham, District Geologist.

Fifeshire and Kinross-shire, 34 N.E.—Kelty. Original survey by H. H. Howell and A. Geikie. Revised by J. K. Allan ; C. H. Dinham, District Geologist.

Stirlingshire, 10 S.E.—Stirling (N. part). Original survey by B. N. Peach. Revised by C. H. Dinham, H. H. Read and D. Haldane ; C. H. Dinham, District Geologist.

Stirlingshire, 18 S.W.—Cowie. Original survey by B. N. Peach. Revised by C. H. Dinham, District Geologist.

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Manuscript copies of the following maps on the scale of six inches to one mile were deposited in the Library for public reference. These maps are not to be published. The English maps are deposited in the head office in London. The Scottish maps are deposited in the Edinburgh Office.

English manuscript maps deposited for reference

Denbighshire, 38 S.W. (part); 41 N.W. (part), N.E., S.W. (part), S.E.; 42 N.W., N.E., S.W., S.E.; 44 N.W., N.E. (part).

Hampshire, 76 N.W., N.E., S.W., S.E.

Montgomeryshire, 5 N.W. (part), N.E., S.W. (part), S.E.; 6 S.W.; 9 N.W. (part), N.E., S.W. (part), S.E.; 10 N.W., N.E. (Shropshire, 25 N.E.), S.W., S.E.

Northumberland, N. 5 S.E.; N. 6 S.W.; N. 10 N.W., S.W., S.E.; N. 14 N.W., N.E., S.E.; N. 15 N.W., N.E., S.W., S.E.; N. 19 N.E., S.E.; N. 20 N.W., N.E., S.W., S.E.; (N. 25 S.W. and S.E.); N. 26 N.W., N.E., S.W.

Shropshire, 11 N.E. (part), S.E.; 18 S.E.; 19 N.E., S.E.; 26 N.W. (Montgomery, 11 N.W.), N.E., S.W. (Montgomery, 11 S.W.), S.E.; 36 N.W.; 37 N.W., S.W., S.E.; 44 N.W., N.E., S.W., S.E.; 51 N.W., N.E., S.W., S.E.; 52 N.W., N.E., S.W., S.E.

Staffordshire, 49 N.W., N.E., S.E.; 50 N.W., N.E., S.W., S.E.; 55 N.E., S.E.; 56 N.W., N.E., S.W., S.E.,; 61 N.W., N.E., S.W. (part), S.E.; 62 N.W., S.W.

Yorkshire, 215 N.W., S.W.; 245 S.W.; 259 N.W.

Scottish Manuscript maps deposited for reference

Argyllshire, 13 S.E.; 14; 15 N.W., S.W.; 23 N.E.; 24; 25 N.W., S.W.

Argyllshire (Coll and Tiree), 36 N.E., S.W., S.E.; 49 N.E., S.W., S.E.; 50 N.W., N.E., S.W.

Argyllshire (Mull), 96.

Ayrshire, 9 S.W., S.E.; 13 N.E.; 14 N.W., S.W., S.E.; 19 N.W.; 25 S.W.; 30 N.W.; 43 S.E.; 44 N.W., S.W.; 50 N.W.

Berwickshire, 7 N.E., S.W., (S.E. and 13a); 8; 9; 10; 14; 15; 16; 20; 21; 22.

Fifeshire, 37 S.W.

Lanarkshire, 26 N.W., S.W.; 34 N.W.; 39 S.E.; 40 N.W.

Renfrewshire, 16 S.W., S.E.; 17 S.W.; 18 N.E.; 19.

Sutherlandshire, 36; 37; 45; 46; 47; 55; 56; 57; 65; 66; 67; 68 S.W.; 76; 77; 78; 79.

List of Maps in the press at the close of 1928

English maps in the press

1 inch to 1 mile :—

Sheet 6.—Alnwick (*Solid and Drift Editions*).

Sheet 22—Maryport (*Solid and Drift Editions*).

Sheet 28.—Whitehaven (*Solid Edition*).

Sheet 153.—Wolverhampton (*Solid and Drift Editions*).

Sheet 217.—Moreton in Marsh (*Drift Edition*).

Sheet 269.—Windsor (*New Drift Edition*).

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6 inches to 1 mile (coalfield maps) :—

Cumberland, 13 S.W.
Lancashire, 87 S.E.; 88 N.E., S.E.; 95 N.E., S.W., S.E.; 96 N.E., S.W., S.E.; 97 N.W., S.W.; 103 N.W., N.E.; 104 N.W., N.E., S.W., S.E.; 105 N.W., S.W.
Northumberland, N.28 N.E., N. 29 N.W., S.W., S.E.; N. 34 S.W.; N. 35 N.W., N.E., S.W.; N. 42 N.W., N.E.; N. 43 N.E.; N. 88 N.E.; (N. 97 S.W. and S.E.).
Shropshire, 19 N.W.; 36 N.E., S.E.; 43 N.E., S.E.
Staffordshire, 62 N.E.

Scottish maps in the press

Index Map :—

Central Coalfield of Scotland showing 6-inch and 1-inch Sheets, on scale of 4 miles to an inch.

1 inch to 1 mile :—

Sheet 8.—Carrick.
Sheet 22.—Kilmarnock (*Soil Texture Edition*).
Sheet 23.—Hamilton (*Solid and Drift Editions*).
Sheet 32.—Edinburgh (*Solid Edition*).
Sheet 67.—Stonehaven.

6 inches to 1 mile (coalfield maps) :—

Ayrshire, 46 N.E., S.E.; 47 N.W., S.W.; 50 S.W.; 52 N.E.
Fifeshire, 32 S.E.; 35 N.W., N.E., (35 S.E. and 36 S.W.); 37 N.E., S.E.; 39 N.W.
Lanarkshire, 3 S.E. (*New Edition*); 19 N.W.; 32 S.W., S.E.; 38 N.W.
Stirlingshire, 18 S.E.

II.—Vertical Sections of Strata

English Vertical Sections published in 1928

Sheet 81.—Sections of Shafts in the Steam Coal Series in the 1-inch map Sheet 232 (parts of Monmouthshire and Glamorganshire). Scale 100 feet to an inch. (*Reprinted.*)
Sheet 84.—Sections of Shafts below the Pennant Grit in the Rhondda Fawr and in the Upper Measures at Llantwit. Scale 100 feet to an inch. (*Reprinted.*)

Scottish Vertical Sections published in 1928

Sheet 14.—Vertical Sections illustrating the Central Coalfield. Limestone Coal Group, Lower Limestone Group and part of Calciferous Sandstone Series in Areas IV and VIII. Paisley, Giffnock, and East Kilbride.

English Vertical Sections in the press at the close of 1928

Sheet 83.—Sections of Shafts in and below the Pennant Grit in the Taff, Aberdare and Rhondda Fach Valleys. Scale 100 feet to an inch. (*Reprinting.*)
Sheet 85.—Sections of Shafts, etc., in the Tawe, Dulais, Neath, Avan, Llynfi, Garw and Ogmore Valleys. Scale 100 feet to an inch. (*Reprinting.*)
Sheet 93.—Sections of Shafts in the Coal Measures of the Abergavenny District (Sheet No. 232) of the South Wales Coalfield, being supplementary to Vertical Sections, Sheet 81. Compiled by T. Robertson.
Sheet 94.—Sections of Shafts and Borings in the Southern Part of the South Staffordshire Coalfield. By Talbot H. Whitehead.

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III.—Memoirs

The following list shows the memoirs published during the year 1928. The work done on them has been mainly the correction of proofs and preparation of indexes.

English Memoirs published in 1928

Summary of Progress of the Geological Survey of Great Britain and the Museum of Practical Geology for the year 1927:—
Part I.—With Report of the Geological Survey Board and Report of the Director. 82 pp.; 1 text-figure. 1928. Price 1*s.* 6*d. net.*
Part II.—110 pp.; 4 plates; 21 text-figures. 1928. Price 2*s.* 6*d. net.*

List of Memoirs, Maps, Sections, etc. Published by the Geological Survey of Great Britain and the Museum of Practical Geology to 30th June, 1928. Price 1*s. net.*

Palaeontology. Vol. I, Part 5.—Plectambonites and Some Allied Genera. By Owen Thomas Jones, M.A., D.Sc., F.R.S., Professor of Geology in the Victoria University of Manchester. 161 pp., 5 plates. 1928. Price 6*s.* 6*d. net.*

Palaeontology. Vol. III, Part 1.—The British Carboniferous Producti: II. *Productus* (*sensu stricto*); *Semireticulatus* and *Longispinus* Groups. By Helen Marguerite Muir-Wood, M.Sc. 217 pp.; 12 plates. 1928. Price 9*s. net.*

Classified Geological Photographs. From the Collection of the Geological Survey of Great Britain. 76 pp. 1928. Price 1*s. net.*

Wells and Springs of Somerset. By L. Richardson, F.R.S.E., F.G.S.; with a bibliography of The Bath Thermal Waters by W. Whitaker, B.A., F.R.S., F.G.S. 279 pp.; Coloured geological map; 3 text-figures. 1928. Price 7*s.* 6*d. net.*

Wells and Springs of Sussex. By F. H. Edmunds, M.A. 262 pp.; 1 plate; 11 text-figures. 1928. Price 5*s. net.*

Wells and Springs of Warwickshire. By L. Richardson, F.R.S.E., F.G.S. 204 pp.; 5 text-figures. 1928. Price 5*s. net.*

The Geology of the Country around Wrexham. (Explanation of one-inch Sheet 121: England and Wales.) By C. B. Wedd, B.A., B. Smith, M.A., Sc.D., and L. J. Wills, M.A., Ph.D. With a contribution by G. W. Lamplugh, F.R.S.
Part II.—Coal Measures and Newer Formations. 237 pp.; 5 plates; 11 text-figures. 1928. Price 5*s. net.*

The Country between Wolverhampton and Oakengates. (Explanation of one-inch Sheet 153: England and Wales.) By T. H. Whitehead, M.Sc., A.R.C.Sc., T. Robertson, B.Sc., Ph.D., R. W. Pocock, M.Sc., and E. E. L. Dixon, B.Sc., A.R.C.Sc. With contributions by T. C. Cantrill, B.Sc., H. Dewey, R. L. Sherlock, D.Sc., A.R.C.Sc., J. Pringle and R. Crookall, Ph.D. 244 pp.; 8 plates; 11 text-figures. 1928. Price 5*s.* 6*d. net.*

The Geology of the Country around Woodbridge, Felixstowe and Orford. (Explanation of one-inch Sheets 208 and 225; England and Wales.) By P. G. H. Boswell, O.B.E., D.Sc., Professor of Geology in the University of Liverpool. 80 pp.; 2 plates; 15 text-figures. 1928. Price 2*s.* 6*d. net.*

The Geology of the Country near Ramsgate and Dover. (Explanation of one-inch Sheets 274 and 290: England and Wales.) By H. J. Osborne White. 98 pp.; 5 plates; 15 text-figures. 1928. Price 2*s.* 9*d. net.*

The Geology of the Country near Hastings and Dungeness. (Explanation of one-inch Sheets 320 and 321: England and Wales.) By H. J. Osborne White. 104 pp.; 6 plates; 14 text-figures. 1928. Price 3*s. net.*

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Scottish Memoirs published in 1928

Summary of Progress.—See p. 29.

The Geology of Arran. (Explanation of Arran District Map, including parts of one-inch Sheets 13 and 21: Scotland). By G. W. Tyrrell, A.R.C. Sc., Ph.D., Lecturer in Geology in the University of Glasgow. 292 pp.; 6 plates; 36 text-figures. 1928. Price 6*s.* 6*d. net.*

English Memoirs in the press at the close of 1928

Attrition Tests of British Road-stones.

Special Reports on the Mineral Resources of Great Britain.—Vol. XXXI.—Ball Clays.

Wells and Springs of Derbyshire.

The Country around Oswestry. (Explanation of one-inch Sheet 137: England and Wales.)

The Geology of the Country around Sudbury (Suffolk). (Explanation of one-inch Sheet 206: England and Wales.)

The Geology of the Country around Aldershot and Guildford. (Explanation of one-inch Sheet 285: England and Wales.)

Scottish Memoir in the press at the close of 1928

The Geology of North Ayrshire. (Explanation of one-inch Sheet 22: Scotland.)

Geophysical Surveying

As was reported in the *Summary of Progress* for last year a field party was engaged at the close of the year in making investigation of the distribution of gravity anomalies in a district about eight miles north-west of Glasgow. This survey was continued in 1928 and the field work was brought to a close in the month of March. The party consisted of Dr. W. F. P. McLintock and Dr. J. Phemister, assisted by three or four of the technical staff who performed the mechanical operations and took part in the field surveying and levelling. This had to be done on a very minute scale in order to provide data for the calculation of the disturbing effect of irregularities in the form of the surface in the neighbourhood of the stations.

The problem investigated was the position, and so far as could be ascertained, the configuration of the old pre-Glacial channel of the River Kelvin. This was known approximately from a series of borings put down many years previously in search of the coals and ironstones that occur in the Carboniferous rocks. The specific gravity of the gravel, sand and other Glacial deposits that fill the old valley was about 1·84 and that of the solid rocks which bound the channel about 2·38, and it was anticipated that this difference was sufficient to give an easily observable effect on the torsion balance. At an early stage in the investigation it was clear that this expectation was fulfilled, as residual gradients up to 45 Eötvös units were observed. On the other hand, the disturbances due to surface configuration were rarely more than 25 Eötvös units, though at a few stations on steeply sloping ground they reached 40 units and over.

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Consequently the nature and even the approximate magnitude of the gravitation anomalies produced by the underlying structures were never in doubt, and the experiment proved so instructive that about 60 stations were ultimately observed in order as far as possible to render the evidence obtainable by these methods complete and definite. The task was to a considerable extent simplified by the local conditions, as the surface was flat in the area which was to be most closely investigated, and as the land was mostly under grass, the difficulties of field work in winter were considerably reduced.

With a short interruption at Christmas this party continued the field work till early in March. When the weather was suitable and the instrument was working smoothly it was usual to complete one station every week-night. Each station requires seven readings, at intervals of about one hour, so that the actual observations require about six hours work under favourable conditions. During the day a very careful and complete survey of the ground around each station was made by means of level and tacheometer. The most onerous part of the work, which is the reduction of the observations and the calculation of the residual effects, remained to be overtaken. Very frequently, however, it was possible to complete a series of preliminary calculations during each 24 hours. In this way the residual gradient at each station was known approximately before the position of the next station was decided on, and the observations made at a new position ; and in practice this proved very convenient, as it ensured that only important stations should be observed, and that any interesting results could be confirmed by a group of subsidiary stations without loss of time and without interrupting the uniform progress of the work.

On the return to headquarters the whole of the observations were calculated afresh and independently by the two geologists in charge and maps were prepared on the scale of twenty-five inches to one mile showing the surface configuration of the ground, the direction and magnitude of the gravitational gradient and the contour-lines of equal anomaly, indicated by the observations.

The results were full of interest as it was proved that the position of the deep valley could be closely defined and that an approximate idea could be formed of its configuration, of the steepness and shape of its lateral slopes, the presence of irregular elevations or humps in the rocky floor, and of branches or tributary valleys. Furthermore, from the observed specific gravities of the sands, clays, gravels and Carboniferous rocks it was possible to calculate the depth of the channel at various places, and where this had already been proved by borings there was a fairly close agreement between the observed and inferred results.

It seems clearly established that in the investigation of problems of this nature the usefulness of torsion balance surveys may be sufficiently great to justify the time and money expended on the work. A preliminary survey carried out without unnecessary

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detail may give much information regarding buried drift-filled channels of which there may be little or no surface indication.

As such problems arise frequently in relation to the construction of canals, reservoirs and tunnels, and in connexion with excavations and foundations, a gravitational survey, followed where necessary by trial borings, promises to give useful results. To some extent also such a survey may form a guide to mining operations, as grave accidents may be occasioned by the unexpected intersection of a deep channel filled by drift, especially where the surface materials are full of water or partake of the nature of a running sand.

Conversely, of course, if the balance can thus detect the presence and approximate distribution of masses of material that have a lower specific gravity than the surrounding rocks it can also detect the presence of heavy bodies in similar circumstances. This was clearly proved in the investigation of the Swynnerton dyke, which was reported in the *Summary of Progress* of last year. This property gives this method its principal economic value in the detection of ore bodies that are denser or of masses of rock salt that are less dense than the strata in which they occur.

The survey of the buried Kelvin valley aroused a good deal of interest among those who study geology, mining and general physics. Dr. Phemister gave a lecture on this subject to the Geological Section of the British Association at its meeting in Glasgow in September, 1928. Lectures on this subject have also been given to the Geological Society of Glasgow and the Royal Astronomical Society, and Dr. McLintock and Dr. Phemister have read a paper giving their results in full detail to the Royal Society of Edinburgh. This paper was in the press at the close of the year and from its treatment of the mathematical problems that arise in the discussion of the observations it is likely to have permanent value as a contribution to the literature of the subject.

Field operations were suspended during the summer months partly because of the pressure of other work and partly because the autumn and winter months are more suitable for this class of investigation. Especially on cultivated land it is of great advantage to work at a season when the crops are off the ground and when there is least damage and interference with agricultural operations. Moreover, the type of balance with which the field party was provided proved to be exceedingly sensitive to changes of temperature and other influences that apparently depend on the height of the sun above the horizon. The instrument is provided with automatic photographic registration impelled by clockwork, and theoretically should work equally well by day or by night and should require almost no personal attention. In practice, however, it was found that the beam is seldom steady during daylight, and all observations must be repeated till oscillation has ceased. In the cellars of the Museum in London automatic photographic registration is quite satisfactory; in the field where the action of the wind is often

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strong and where there are rapid changes of temperature, apart from the varying influence of sunshine and shade, it is necessary to observe every precaution if much time is not to be lost. Consequently the observers have, after repeated trial, decided to depend only on visual observations made after sunset and before sunrise. As at least six hours are needed for the observations at each station it is an advantage to do the field work at those periods of the year when the nights are long; even in these circumstances, however, the presence of a strong wind or the rapid fall of temperature due to a clear frosty night may make some or all of the results unsatisfactory and may necessitate repetition under more favourable conditions.

An experiment was made during the summer to find a means to obviate these difficulties. The balance was erected in the grounds of the National Physical Laboratory at Teddington and a special canvas tent, of bell shape, was placed around it to provide shade and shelter from the wind. The observations made in this way were better than with the instrument surrounded only by the metal tent that is provided with the apparatus, but they were not completely satisfactory and for this and other reasons the further prosecution of gravitational surveys was postponed till near the close of the year.

Another factor which must be kept in mind is that the mere calculation of the results involves more expenditure of time than the actual operations in the field, and consequently, if the two sets of proceedings can be carried on concurrently, there is no actual waste of time by accumulating observations under favourable circumstances at such a rate that reliable preliminary results can be attained day by day during the progress of the field work.

It was decided to undertake another programme of geophysical work during the autumn season and the problem selected was one involving geological structure or tectonics. The operations of the Anglo-Persian Oil Company in Persia have proved that the torsion balance can under suitable conditions detect the presence of an anticlinal fold (*Summary of Progress* for 1926, Appendix XII, pp. 168-196; see also *Monthly Notices Roy. Astron. Soc., Geophys. Supplement*, Vol. II, No. 1, 1928). As a further test it was proposed to investigate some well marked fault or fracture line, bringing together rocks of different age and differing not too widely in composition and in specific gravity. After careful inspection a site was chosen in the neighbourhood of Portobello, about three miles east of Edinburgh. The rocks of the Midlothian coalfield which lie in a great syncline are faulted against Carboniferous rocks belonging to a lower horizon by a great fault which is well known to local mining engineers and runs out to sea east of Portobello. The position of this fault is known with sufficient definiteness though the fault is not actually exposed, and on inspection it proved that parts of the country traversed were sufficiently level to make a gravitational survey practicable. Moreover, there was no reason to suspect the presence of irregular rock surfaces or buried channels beneath

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the superficial deposits which everywhere in the district overlie the Carboniferous rocks. Permission was readily obtained from the farmers who cultivate the land ; and we are indebted to them for granting every facility for the work. The balance after a thorough overhaul in London was sent to Scotland about the middle of October and within a few days after it had been erected on the ground it was found to be sufficiently steady to enable observations to be started.

As the position and direction of the line of fault were approximately known the first proceeding was to establish a line of stations perpendicular to the line of fault and crossing its probable course. This was accomplished in a few days and it was found that while the gradients were nearly constant in direction they varied greatly in amount. At a place about 200 yards from the line marked on the six-inch geological map as the conjectural position of the fault the gradients rapidly increased in a westward direction. When their magnitudes were plotted against the distances between the observed stations the resulting curve was in striking accordance with the theoretical curve for a fault bringing into juxtaposition two rock masses of strikingly dissimilar density. As a matter of fact the magnitude of the gradients was unexpectedly large, some of them being as high as 85 Eötvös units. Consequently there seemed no room for doubt that the balance had detected the presence of an important geological structure below the covering of drift and alluvial deposits. This covering, it may be remarked, is believed to be from 60 to 100 feet thick, but its thickness is not known, as there are no borings and no natural exposures sufficient to give reliable evidence on this point.

In order to obtain as much information as possible about this interesting line a set of stations was observed, about 25 in number, along a distance of rather more than half a mile. Preliminary calculations and reduction of the observations yielded a graph of very characteristic form but at the same time presenting certain irregularities that invited further discussion.

It seemed obviously desirable to check or confirm these results by observations along other lines parallel to the one first selected. For this purpose two other lines were surveyed to the south-west of the first one and several hundred yards distant from it. The surface being nearly level was well suited for the purpose and the ' terrain ' corrections due to irregularity of the ground were in no case very troublesome. The second and third lines of survey amply confirmed the results of the first but each of them showed minor peculiarities of a highly interesting character. In spite of rather inclement weather the field work was practically finished by the end of the year, and the surveyors returned to the office, where all the calculations were repeated and the observations corrected and reduced.

A special report is now being prepared on the results of this geophysical survey, and until that report is completed it is premature

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to enter into detailed discussion or to formulate conclusions. It may be pointed out, however, that the high gradients observed near the fault line may be explained if the rocks on the west side are much more dense than those on the east of that line. Now on the west the Lower Carboniferous rocks are near the surface and in that series occur the well-known lavas of Arthur's Seat. From all the evidence obtainable from surface exposures these lavas were believed to lie at a considerable depth, covered over by shales and sandstones. There is no way of proving the actual facts except by means of a bore, but it seems quite probable that the lavas are not so deeply buried as was conjectured. If the lavas are at or near the surface the problem is similar to that which was previously investigated at Swynnerton, where a basalt dyke is in contact with Triassic marls and sandstone. The gravitational survey at any rate has raised an interesting problem on which light may be thrown at some future date.

As regards the irregularities presented by the graph of gravitational anomalies in the immediate vicinity of the fault line, there is more than one explanation that may prove applicable. This is an important fault having a large displacement, and in such cases it is not unusual to find a belt of broken rocks many yards in breadth in place of a sharply cut fault fracture. This would occasion a sensible alteration in the gradients as the fault belt was crossed and might even in imaginable circumstances cause a local reversal of the gradient if the mass of rock which lies between the boundaries of the fault zone was of very different character from the other rocks in the neighbourhood.

Among the numerous possible explanations for irregularity in the gradients it may also be kept in mind that the fault may split into two or more branches which may diverge for a space and then come together again enclosing a mass belonging to a different horizon and of different physical properties.

Again it is conceivable that as the whole district has been intensely glaciated the broken rock in the fault line may have been eroded into a trough which was subsequently filled with loose surface materials. In this case there would be a buried channel which, if it was sufficiently pronounced, would certainly have an influence on the gravitational gradients.

Discussion of these matters may, however, be left over till the observations have been reduced and reported on. It is sufficient for the present to point out that in this instance as in the previous ones the Eötvös balance has not failed to detect the geological structure which was previously known to exist in the ground examined, and under the circumstances in which it has been employed has proved to be a scientific instrument capable in skilled hands of yielding results not only of theoretical interest but also of practical value. Our programmes of work accordingly may be regarded as successful, as they have always accomplished at least

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as much as was anticipated when they were planned. These new methods of investigation have received very careful study and trial in the field, and a staff has been trained to carry them out in a thoroughly efficient manner.

In last year's *Summary of Progress* it was mentioned that an Australian scientist had received theoretical and practical training in work with the Eötvös balance under Dr. McLintock and Dr. Phemister. Since that date work has been started in Australia on the same lines as in Britain, and an extensive programme of geophysical survey is contemplated.

During 1928 the Research Council of Canada sent over Mr. A. H. Miller to study methods of geophysical observation and survey in Europe, and on the invitation of the Director of the Geological Survey of Great Britain he joined our geophysical unit and worked with them for a time. After some weeks spent practising with the balance in London he proceeded to Scotland and took part in all the field work and the calculations, obtaining a full practical knowledge of the methods which we employ and giving valuable assistance and information to our geologists. It is understood that a programme of field survey with the Eötvös balance may be undertaken in Canada on his return.

Having made several successful researches with the gravitational balance it seemed desirable to try the other instruments which are used for geophysical surveys. After full discussion and consideration it seemed most likely that magnetic surveys would yield useful results with the time and staff at our disposal. There are many problems in Britain on which magnetic surveys may be expected to throw light, and not much of that kind of work has been done, though in 1919 Dr. Walker and Professor Cox published a valuable series of observations on magnetic variation in relation to geological structure.[1] Their conclusions encourage further research, though it is clear that this method, like the others, is specially adapted for the solution of a certain class of problems and cannot be universally applicable. At the close of the year orders had been placed for a vertical and a horizontal magnetometer of standard pattern. As soon as the instruments are received and have been tested a course of magnetic surveys will be taken in hand. Assistance has been promised by the Research Officer of the Ordnance Survey, who is at present engaged in a revision of the magnetic map of Great Britain. It is quite clear that magnetic surveys will be very useful to confirm and extend the results of some of the gravitational surveys that we have already executed. For example the Swynnerton dyke will probably be as easily detected by the magnetometer as by the torsion balance. As soon as possible in the coming year these matters will be put to the test and the results will be as freely published as those of the gravitational surveys have been.

[1] *Phil. Trans. Roy. Soc.*, Series A., vol. 219, 1919.

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Soil Mapping

The attempts which have been made during the last three years to secure active collaboration between the field surveyors of the Geological Survey and the soil experts of Agricultural Colleges who are engaged in testing and classifying the soils of their districts have been continued during the past year and notable results have been achieved. The best methods of classifying soils for the purposes of mapping are not yet agreed upon, and at the present stage every opportunity should be taken of bringing geologists and agriculturists together to the study of some important problem in the field. With this object in view the Development Commission and the Ministry of Agriculture and Fisheries again arranged for a joint visit of geologists and agriculturists to a selected locality to secure discussion and collaboration. This year's conference was held at Oxford in September.

Mr. Howe reports that the Survey was represented by Messrs. T. Eastwood, F. H. Edmunds and J. B. Simpson. The programme before the conference was the study of methods of soil mapping in an area of forest land, the selected site being part of Bagley Wood, near Oxford.

The chosen area is one of moderate relief in which the following geological succession occurs from the higher ground to the lower :— Plateau Gravel, Kimmeridge Clay, Coral Rag, Calcareous Grit and Oxford Clay.

In the opinion of Mr. R. Bourne, of the Imperial Forestry Institute, Oxford, the area was probably originally covered by scrub oak, but about 30 years ago parts had been planted with various kinds of timber in quarter acre plots.

The field party worked in sections, each of which produced a map of its portion of the ground ; these were then compared and studied jointly. Small augers were employed for examination of the subsoil, and attention was particularly directed to the question of podsolization. Certain analyses were to be made to throw light on the degree of podsolizing in a typical profile in the Plateau Gravels, and others to determine the correct texture of some of the soils. The results of these analyses have not yet been received.

In regions such as the one under investigation it would appear that the geological drift map on the six-inch scale is a sufficiently close approximation to the representation of the soil distribution, from the point of view of soil origin. The chief difference between the geological map and the soil surveyors' maps, in this case, lay in the fuller representation of down-wash effects on the latter ; though the presence of such feather-edge deposits and down-washes should be fairly obvious from the geological map, when the outcrops and relief forms are considered in relation to one another. Notes are now being made by the geological surveyors upon maps of areas under survey, which should go a long way towards meeting the requirements of the soil surveyors.

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As regards the progress of soil surveying in Scotland during the past year Mr. Macgregor has sent in the following report :—

Reference was made in the *Summary of Progress* for 1927[1] to the work undertaken by the late Professor R. A. Berry and by his assistants in the Chemistry Department of the West of Scotland Agricultural College on the soils of the Kilmarnock area (Sheet 22, Scotland). The ' soil texture ' map which they had prepared is in course of publication, and three editions of Sheet 22 will thus be available, one showing the ' solid ' geology, another showing the distribution of the superficial deposits, such as boulder-clay, sand and gravel, etc., and a third showing that of the soils classified according to textural differences. It will thus be possible by means of these maps to study the relationships of the various soil texture groups to the underlying ' drift ' and 'solid ' formations. The account of the soils and agriculture of the same area which Professor Berry and his assistants undertook to prepare was completed early in the year, and will form a very useful contribution to the memoir on Sheet 22 ('Geology of North Ayrshire '), now in the press. In this account the soil texture groups—light sands, heavy sands, moderately light loams, moderately heavy loams, heavy loams, and clays—are dealt with in succession, and their distribution, properties and agricultural characteristics described. In each case the nature of the underlying ' drift ' and ' solid ' formations is indicated, and introductory sections to the detailed account deal with ' Topography and Climate,' ' Methods of Research,' ' Soil Classification ' and ' Relation of Soils to Geology.' Tables of mechanical analyses are included and the illustrations comprise a simplified topographical map showing the distribution of the texture groups by means of ornament, a rainfall map of the area, and a number of mechanical composition curves. It should be stressed that mapping and classification of the soils are based on a single factor, that of texture. Owing to the size of the area (390 square miles) and the limited time available, a detailed survey of soil profiles was out of the question. The soils were examined by means of an auger to a depth of 30 in., and, where natural or artificial cuttings could be found, to as great a depth as possible. Field tests of acidity were carried out, and observations made of colour, stoniness, drainage, water table, contour of ground, soil profile, quality of pasturage and crops, etc., while as much information as possible was obtained from County Organisers and from farmers regarding rotations, manures, cropping and stocking powers of the land and rentals.

It is much to be regretted that Professor Berry died before the manuscript was finally ready for the press. He took the greatest possible interest in soil surveying work, and welcomed wholeheartedly the idea of close co-operation between the Agricultural Colleges and the Geological Survey. His death is a great loss to

[1] *Mem. Geol. Surv.*, Pt. I, 1928, p. 22.

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Agricultural Science. Acknowledgment should be made of the assistance rendered by his successor, Professor D. N. M'Arthur, D.Sc., F.I.C., in carrying out certain modifications in Professor Berry's manuscript which were required to bring it into conformity with the rest of the memoir of which it forms part.

In continuation of the work in North Ayrshire Professor Berry and his staff had agreed to undertake a similar examination of the soils of South Ayrshire, and a considerable area in the south-west of Sheet 14 was surveyed during the past summer. Laboratory tests of the soil samples so far collected are at present proceeding in the West of Scotland Agricultural College, and the work, it is hoped, will be continued during 1929 under the supervision of Professor M'Arthur.

Inspection of Bores and Shafts

Every opportunity has been taken of collecting new information under the facilities granted by the Mining Industry Act (1926) from borings and sinkings in progress in mining districts. Probably on account of the depression in the coal trade during the past year the amount of boring has not been so great as might have been anticipated, but two officers of the Survey, Mr. Templeman in England and Mr. Manson in Scotland, have been fully employed visiting borings and shafts, obtaining records of the strata passed through, and collecting specimens of rocks and fossils. The bore journals are very carefully checked and compared with the cores which have come out of the bore. The specimens are registered and added to our rock and fossil collections after they have been determined by our geologists and palaeontologists. In Scotland many of the bore records are drawn up in graphic form, which renders them immediately useful for direct comparison with similar graphic journals of bores from other districts. The exact site of each bore is a matter of considerable importance, especially in districts where there is a good deal of faulting; this is ascertained very carefully and in addition to being recorded on the written copy of the bore journal is marked on the six-inch working copies or bore maps in the collections of the Geological Survey so as to avoid all ambiguity in the future. The bore records are kept in a series of files according to counties and six-inch quarter-sheets. The number of borings varies greatly in different coalfields; some Scottish quarter-sheets covering six square miles have between 200 and 300 bores marked on them. Many of these borings have little geological interest, having been put down only for practical purposes such as to ascertain the depth, thickness and condition of a coal seam well known to occur in that locality. All the deeper or exploratory borings, however, are of great importance to the geologist as often no other information is to hand regarding the sequence and structure in that part of a coalfield and a well executed boring gives very exact and complete particulars regarding all the strata through which it passes.

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Compulsory notification of mineral bores exceeding 100 feet in depth has now been provided, but similar conditions do not apply to borings in search of water. In the South and East of England many deep wells are sunk every year; most of the principal firms engaged in this work are in close contact with the Survey geologists, whom they consult frequently as to the depth of water-bearing strata and the chances of obtaining satisfactory supplies of water. These firms generally supply us freely with information regarding the wells which they make, whether successful or not. The amount of information on this subject increases every year, and a vast amount of it has been published in the Water Supply Memoirs which are well known to engineers and borers in all parts of the country. Wherever these borings are likely to throw light on the stratigraphical succession and structure of the country they are visited by members of the staff, who check the bore records and collect rocks and fossils. It is probable, however, that a certain number of these bores escape notice at the time when they are made and thus it becomes impossible to obtain full particulars regarding the characters of the rocks penetrated and to clear up doubtful points in the records. The Geological Survey is greatly indebted to the kindness of those firms who supply information regarding borings in progress and no effort is omitted to obtain reliable and complete records during the course of the work.

Mr. Howe reports that the number of new borings and shaft sinkings notified in England during 1928 was 9. At the beginning of the year 44 borings that had been notified were still in progress, of which 19 have been completed and 4 have been temporarily suspended. Mr. Templeman has visited 41 boreholes, obtained 51 bore records and collected 726 specimens from borings and shafts. Many visits have also been paid to borings by geologists in search of information regarding the geology of various districts in England. The rest of Mr. Templeman's time has been occupied in arranging the sets of boring records in the London office.

Mr. M. Macgregor reports that in Scotland notification was received of 24 borings and sinkings during the year and several of these included two or more bores or shafts. Not only have the journals been obtained and checked but the preparation of graphic sections has also in practically all cases been carried out. Among the more interesting points which emerge from the boring information obtained in Scotland during the year the following may be noted:—

In a shaft sunk at Mauchline (No. 4 Pit, Mauchline Collieries) the Tourha' Coal was met with at a depth of 36 fathoms 4 feet, and on driving a heading in this seam near the bottom of the shaft the coal was found to pass laterally into a dark grey argillaceous limestone, 1 foot in thickness. Specimens tipped at the surface and examined by Mr. Manson showed that the limestone consists of a

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central granular portion, 4 inches thick, overlain and underlain by an equal thickness of limestone with well developed cone-in-cone structure.[1]

A boring at Kerse, near Patna, proved the occurrence of Skipsey's Marine Band at a depth of 73 fathoms, while 11 fathoms lower a burnt coal overlain by 2 feet of blaes (shales) containing *Lingula squamiformis* represents the position of the well-known Craigmark Ironstone.

A boring near Wishaw (at Garriongill Colliery) and a sinking at Kingshill Colliery, Auchterhead Muir, provide interesting evidence of the extension into these localities of the unconformity near the base of the Millstone Grit Series which has been shown by Mr. C. H. Dinham to be present throughout the Stonehouse-Larkhall-Dalserf district.[2] The Garriongill Colliery bore indicates that here the thickness of the Millstone Grit is reduced to about 20 fathoms, mainly of sandstone, unconformably overlying strata referable to the upper part of the Upper Limestone Group.

The marine horizon which occurs in the Black Metals of the Central Coalfield, near the middle of the Limestone Coal Group, has been recorded in the cores of a blind boring at Foulshiels on the east side of the Lanarkshire basin. An interesting suite of marine fossils was obtained by Mr. Manson from the roof of a coal in the lower part of the Limestone Coal Group in a boring near Blair Mine, Oakley, in Fife. By means of these fossils it is possible to correlate the coal in question with the Smithy Coal of Bo'ness, from the roof of which Mr. H. M. Cadell, many years ago, obtained a very similar assemblage.[3]

Conferences

The first Conference of the Surveyors General of Dominions and Colonies, convened by the Secretary of State for the Colonies, was held in London and Southampton between July 2nd and 13th. An officer of the Geological Survey was in close touch with the Conference throughout the proceedings, and there can be no doubt as to its great value as a means whereby expert experience from all parts of the Empire could be brought to bear upon problems common to all.

Naturally the Conference was concerned mainly with questions connected with trigonometrical and topographical surveys, but such papers as that given by Lieut-Colonel M. N. Macleod on 'Some Problems of Revision' and that on 'Lettering on Maps' by Captain J. G. Withycombe were of considerable interest to the makers of geological maps and gave rise to helpful discussions. At the

[1] *Cf.* Strahan, A., 'On the Passage of a Seam of Coal into a Seam of Dolomite,' *Quart. Journ. Geol. Soc.*, vol. lvii, 1901, p. 297.

[2] Dinham, C. H., in 'Econ. Geol. Central Coalfield, Area IX' (*Mem. Geol. Surv.*), 1921, pp. 76-79.

[3] Cadell, H. M., 'The Fossiliferous Rocks of Borrowstounness Coal-field,' *Trans. Edin. Geol. Soc.*, vol. iv, part iii, 1883, pp. 319-337.

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request of Colonel F. S. Winterbotham a meeting was held in the Museum of Practical Geology on July 7th, when an address was given by Mr. J. Allen Howe on the work of geological surveys and their relation to topographical surveys, a summary of which was circulated to members of the Conference. A large exhibit of geological maps was arranged in the Museum to illustrate types of maps and methods of treatment, with examples from all parts of the world. At the close of the meeting Dr. W. F. P. McLintock demonstrated the Eötvös Balance to a number of members who were interested in geophysical methods.

In June an International Meeting of geologists was held in Copenhagen in celebration of the 40th anniversary of the Geological Survey of Denmark. Practically every country of Europe sent representatives to this meeting. The Director attended as representative of Great Britain and had an opportunity of visiting some of the most instructive exposures and discussing the methods of mapping and the problems of Danish geology with members of the Danish Geological Survey.

At the meeting of the British Association, held in Glasgow in September, the Geological Section (Section C) met under the presidency of Mr. E. B. Bailey, M.C., B.A., of the Scottish Survey staff. By kind permission of the authorities of Glasgow University a room, in close proximity to the lecture hall assigned to Section C, was set aside for the purpose of an exhibition of Geological Survey maps, sections, memoirs, photographs, and drawings. The material exhibited included a number of recently-issued one-inch Scottish maps. Some of the revised maps of Carboniferous areas on the scale of six inches to a mile were also exhibited as well as examples of the Sheets of Comparative Vertical Sections which have been published in recent years to illustrate the sequence in the coalfields of West and Central Scotland. The meeting was well supported by members of the Geological Survey of Scotland, several of whom read papers and contributed to the discussions.

Staff Changes

The Survey has experienced a severe loss by the death of Dr. Gabriel Warton Lee, who joined the staff in 1907 and was well known for his work on Scottish palaeontology. Dr. Lee had not been in robust health for some time, but his death was sudden and unexpected. Educated at Geneva, he had specialised on the fossils of the Scottish Mesozoic and his contributions to the Survey memoirs on Raasay (1920), Mull (1925), and Golspie (1925) will prove of lasting value, but he had also an exceptionally good all-round knowledge of his subject and for many years he did practically all the Carboniferous palaeontology that was required by the work of the surveyors in Scotland. He is the author of a monograph on the Trepostomata in our series of Palaeontological Memoirs. During

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the early years of his service on the staff he did very useful work in the field in the island of Mull and other localities in the West of Scotland. As a museum officer he had exceptional qualifications and the fine series of fossils exhibited in the Survey gallery of the Royal Scottish Museum owes much to his judicious selection and authoritative determination.

Mr. E. M. Anderson, Senior Geologist, belonging to the Scottish staff, has been retired from the service owing to prolonged ill-health.

In September, after a selection by the Civil Service Commissioners, two geologists were appointed to the staff, viz., Dr. C. J. Stubblefield and Mr. W. Q. Kennedy. Of these the former has been assigned to work in England, while Mr. Kennedy has joined the Scottish staff.

Office Accommodation in Edinburgh and Manchester

The transfer of the Scottish headquarters from George Square and George IV Bridge to Southpark, 19, Grange Terrace, Edinburgh, was effected during the month of May and required about three weeks. In spite of the dislocation of ordinary work during this time it was possible to carry on the usual programme without serious interruption. The new offices are situated in a large and roomy house around which there is space for further buildings when these are required. Before the removal the Office of Works installed central heating and electric lighting and made a number of necessary repairs to the structure and roofs. It has been found, however, that the storage space is less than was anticipated and the library and collections are excessively congested and require room for expansion. Many of the rock specimens have to be stored in parcels in an underground cellar which is not suitable for this purpose, and the library is so filled with bookcases that there is not sufficient space for tables on which maps and sections can be spread out. It is very desirable to have a room in which the public who wish to consult manuscript maps can do so in comfort, for many of these maps cannot be seen except in the Edinburgh office. Requests were consequently put forward for the provision of a storage-building in which rocks and fossils could be permanently placed. This would greatly increase the working space and accelerate the work. Draft plans of such a building have been prepared and it is hoped that ultimately, if not immediately, a convenient and well lighted storage-building will be erected in close proximity to the offices in order to accommodate the ever-growing reference collections.

In March, 1928, the Manchester branch office was transferred from 21, Albion Street, Gaythorn, to 270, Oxford Road. The staff in Manchester comprises one district geologist, three geologists and a draughtsman, and their work is entirely directed to the preparation of new maps of the Lancashire coalfield. The new quarters have proved reasonably suitable and have the advantage of being

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very near the Museum and the University. The building in which this office is situated is occupied jointly by the Geological Survey and the Ministry of Pensions.

Collaboration

The Survey continues to receive most valuable support from professional and amateur geologists of eminence. Professor P. G. H. Boswell, of Liverpool University, has had in hand the proofs of two memoirs, one on Woodbridge, Felixstowe and Orford, and one on Sudbury. He has also given assistance in several questions of sedimentary petrology. Mr. E. S. Cobbold has undertaken the study and description of the Cambrian fossils from a district in Shropshire that has been mapped by Mr. Pocock. Dr. Gertrude Elles, of Newnham College, continues to name all graptolites which are collected by the Survey, and her authority on this subject is unquestioned. Mr. L. Richardson has contributed the manuscript of a Water-Supply Memoir on Leicestershire, in addition to revising proofs of his memoirs on Somerset and Warwickshire, and the typescript of memoirs on Worcestershire and Gloucestershire. Dr. G. W. Tyrrell, of Glasgow University, has passed his memoir on Arran through the press, and Dr. R. Campbell, of Edinburgh University, has prepared a new edition of the Stonehaven Sheet (67), and is writing notes for a corresponding memoir. Miss Muir-Wood and Professor O. T. Jones have assisted in the final corrections of their memoirs on *Productus* and *Plectambonites*, which were published during the year. Mr. Hemingway has contributed some very useful information on Carboniferous fossil plants, and Dr. A. E. Trueman has given an authoritative opinion on species of Carboniferous mollusca. Mr. E. J. Lovegrove has given every assistance in the preparation of the handbook to British Roadstones. The Old Red fossil fishes that are being collected in the Orkneys are being determined by Professor D. M. S. Watson, of University College, London, while the fossil plants are investigated by Professor W. H. Lang, of Manchester University. Mr. S. S. Buckman has again acted as specialist on Jurassic cephalopoda, while Dr. L. F. Spath has also contributed notes on other fossils of that group. In the determination of Carboniferous corals we have again had the assistance of Dr. Stanley Smith, of Bristol University, and Professor Hawkins, of Reading University, has investigated Cretaceous echinoids. Mr. W. S. Bisat continues to determine for us specimens of Carboniferous goniatites which are proving to be of much value for zonal correlation in our work in the Lancashire and Yorkshire coalfields.

Mr. Osborne White has completed the manuscript of a memoir on the Saffron Walden Sheet (205), but publication will not be undertaken till the maps of that district receive the necessary revision, as they are in some respects not up to modern standard.

To these and to many others who have proffered information and advice on topics of British geology the Survey is deeply indebted.

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It is with great regret that we record the death of three eminent scientists who have done much to support the Geological Survey in their respective fields of research. Dr. John Horne died in May, 1928, and till within a few days of his death he was engaged in correcting manuscript copies of some of the maps which he and Dr. B. N. Peach had revised in the South of Scotland many years ago. From his wide experience, his great knowledge and his deep sympathies he had been the most valued counsellor and supporter of the Geological Survey of Scotland ever since his retirement in 1911. The whole of the memoirs and maps that Dr. Peach and he had worked on in Scotland during their long periods of service have now been published or prepared in standard form for reference, signed by the authors, and deposited in the Edinburgh office for public use. This makes an immense contribution to Scottish geology, which has never been equalled for variety, for originality and for thoroughness. His death removes from our list of collaborators its most distinguished name.

The death of Sir Aubrey Strahan, Director of the Geological Survey and Museum of Practical Geology from 1914 to 1920, took place at his residence at Fairfield, Goring, Oxfordshire, on March 4th, 1928. Sir Aubrey had served on the Survey for 45 years, having entered as Temporary Assistant Geologist in 1875. He had a special claim for recognition as apart from his distinguished services to geological science he conducted the Survey with great skill and success through the difficult and strenuous years of the Great War, and after peace had been proclaimed he played a prominent part in the reconstruction by which the institution was reorganised on its present footing. Since his retirement he had contributed little to Survey publications but he wrote a short handbook on the Geology of the Thames Valley near Goring as illustrated by the Model in the Museum of Practical Geology (1924); and had never failed to give advice and support when problems of administration were submitted to him.

Professor R. A. Berry, whose death was sudden, had up to the close of his life been actively engaged on field work in Ayrshire, preparing maps showing the distribution of soil types classified mainly according to texture. He combined the most skilled agricultural training with an intense interest in geology; and his work on that subject in Scotland was yielding results of great value and was being closely followed by geologists and by agriculturists.

Palaeontology

ENGLAND AND WALES.—During the year nearly 13,000 specimens of fossils were added to the collections. Apart from the acquisitions by presentation or by purchase, 7,365 specimens have been incorporated in the reference collections and entered in the registers. The number of specimens received by presentation and

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by purchase was 5,612, and of these 3,432 were entered in the registers. The more important of the special sets thus obtained included the following: a collection of 2,300 specimens brought together by the late G. W. Butler, chiefly comprising well collected Cretaceous fossils from localities in Surrey; a collection of more than 1,500 specimens, mostly from the lowest beds of the Chalk in Wiltshire, bequeathed to the Geological Survey by the late Dr. B. Pope Bartlett; a series of 730 specimens (from the collection of the late N. T. Wetherell) presented by Mr. C. W. Hobley, mostly Eocene fossils from localities in the London neighbourhood no longer accessible for collecting; and collections of fossils from the Chalk formed by Mr. A. G. Davis and by Mr. G. W. Young, illustrating their published papers.

Dr. Kitchin has been largely engaged in supervision and editorial duties. Mr. Pringle has studied and named extensive sets of fossils obtained in the areas within a number of sheets in process of being surveyed, while other specimens from these sets and from the Museum have been submitted to specialists who are not members of the staff. The determination of the fossils collected could not be completed within the year, and is still in progress. Mr. Pringle also named the fossils obtained in several borings and drew up lists of the determinations of specimens required in the preparation of a number of sheet memoirs, assisting also by reading the proofs of certain memoirs.

Mr. Pringle paid several visits to the area in the Shrewsbury Sheet, and gave help to Mr. R. W. Pocock in connexion with the Lower Cambrian rocks exposed in trenches made by him at Charlton Hill. He also examined the basement-beds of the Coal Measures at localities between Lilleshall and Little Wenlock, and showed that the rocks at Oldfields Limeworks (near the Wrekin), previously mapped as Coal Measures, are in reality of Lower Carboniferous age. Mr. Pringle paid three visits to shafts in process of sinking at Cefn-coed, near Neath, where numerous fossils were collected from the marine bands passed through there. While in South Wales he devoted some attention to the Millstone Grit, in connexion with the revision of Sheet 230. He also paid a visit to West Cumberland to examine and collect from the Lower Carboniferous rocks at localities near Aspatria.

During the year Mr. Chatwin has been engaged chiefly in work connected with unregistered series of fossils in the collections of the Survey, and with recent acquisitions. Among the more important collections that he named and registered are an extensive series of fossils from the Yorkshire Chalk, from the collection made by the late G. W. Lamplugh; a part of the collection of the late N. T. Wetherell presented by Mr. C. W. Hobley, chiefly Tertiary Mollusca; the collection of fossils from the Chalk of Surrey presented by Mr. G. W. Young; and a zonally important series of fossils from the Upper Chalk of Sussex, presented by Mr. C. T. A. Gaster.

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Mr. Chatwin also examined and arranged the series of Chalk fossils in the collection transferred from the Museum of the Geological Society (preparatory to their registration by Miss M. E. Odell), for the purpose of relegating to a duplicate set the specimens not required for permanent retention. He collated the collection of Eocene, Cretaceous, and Jurassic fossils made by the late Gerard Weedon Butler. He visited Bourton, Dorset, to arrange for the removal of the Pope Bartlett Bequest, and afterwards collated that collection and selected, named, and registered a series from it for the Museum.

The fossil-collecting in connexion with the current Survey work was carried out by Mr. S. W. Hester and Mr. W. Dewar. This entailed visits to the districts in Sheets 152 (Shrewsbury), 166 (Church Stretton), 84 (Wigan), 85 (Manchester), 77 (Huddersfield), 86 (Glossop), 87 (Barnsley), 99 (Chapel-en-le-Frith), 23 (Cockermouth), 231 (Merthyr-Tydfil), 350 (Torquay), and 286 (Reigate). Mr. S. W. Morgan has attended to the registration of Museum specimens, the despatch and return of large numbers of specimens sent out for study, and the increasing duties involved in the miscellaneous work of the office.

Good progress has been made in the registration of specimens. Miss M. E. Odell was engaged for ten months in carrying on that essential work. She continued the registration of the fossils in the large collection formerly in the possession of the Geological Society, and devoted attention also to some of the recent acquisitions.

Numerous enquiries have been answered, and assistance has been given to advanced students and research-workers. More than 2,000 specimens have been sent out to private workers and to specialists for the purpose of study and determination, while 3,771 specimens from the Palaeontological Department were placed temporarily in the hands of other members of the Survey staff; more than 3,400 of these were retained for study in the Manchester Office.

SCOTLAND.—1,718 specimens were added to the collections during the year. These fossils were obtained mainly from the Old Red Sandstone and Carboniferous rocks occupying areas in Sheets 14, 15, 22, 23, 31, 117, 118, 119, 120, and 122. Nearly half of the total collected are fossil fishes and plants from the Old Red Sandstone of Orkney and the Isles of South Ronaldshay, Sanday, and Eday. The Carboniferous fossils were mainly obtained from the cores of borings made in Ayrshire, Lanarkshire, Clackmannanshire, and Fife. The collecting of the material was carried out by Messrs. Tait, Fisher, and Strachan, Mr. Manson dealing with most of the borings.

Apart from the fishes from the Old Red Sandstone, which were submitted to Professor D. M. S. Watson, F.R.S., the examination of the specimens was made by the late Dr. G. W. Lee.

The transfer of the Survey collections to the new offices required a considerable amount of attention; nevertheless, much use has been made of the stored material by workers engaged in the study of special groups of fossils.

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No additions have been made to the exhibited Survey Collection in the Royal Scottish Museum, but there has been some progress in the revision of the naming of specimens shown there.

Palaeobotany

The number of fossil plants added to the collections (by purchase and presentation) during the year was 676. These were chiefly from the Coal Measures in the area covered by the Merthyr Sheet which is now under revision. They have already yielded five new species which have been described by Dr. Crookall. In addition, 20 micro-preparations of various types of coals were purchased from Mr. J. Lomax, of Bolton, and 23 micro-sections of British fossil plants from Mr. W. Hemingway, of Derby.

Loans of specimens for research purposes were made to Professor T. G. Halle, of Stockholm (12 examples of *Lagenospermum*), and to Mr. W. Hemingway (22 specimens of *Rhabdocarpus*).

A considerable amount of time has been spent on current palaeobotanical work in identifying the specimens sent in from the districts at present under survey, and in connection with the palaeobotanical sections for the Ayrshire and Huddersfield Memoirs.

An alphabetical catalogue of the 4,000 photographic negatives in the Kidston Bequest has been prepared.

The Kidston Collection of fossil plants continues to be of considerable use to palaeobotanists, and the following have availed themselves of the collection during the year; Professor A. C. Seward, Dr. D. H. Scott, Professor W. H. Lang, Professor T. G. Halle, Miss E. M. Dix, Mr. W. Hemingway and Mr. W. D. Ware.

In the course of his work, Dr. Crookall has made 5 micro-sections of fossil woods, 16 micro-photographs, 27 photographic negatives, and 282 prints, as well as a number of transfer and maceration preparations.

Petrography

Work in the Petrographical Department has been carried on by the Petrographer, aided by several members of the Geological staff whose field-duties had taken them into regions of igneous rocks. The Petrographer, apart from dealing with many enquiries from the public, Government departments, and officers of the Survey, has been mainly concerned with the petrography of the Tertiary igneous centre of Ardnamurchan. This has entailed the description and review of about a thousand sliced rocks from the region, and a close comparative study of the collections from the neighbouring Scottish Tertiary centres of Mull, Skye, Arran, etc. Mr. E. B. Bailey has been engaged on an examination of the metamorphic rocks and the later igneous intrusions of Coll.

Igneous rocks from the Lleyn Peninsula have been described for Dr. C. A. Matley, and Dr. Thomas, with Mr. W. Anderson, has

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completed the description of the material collected from the Cheviot Hills and surrounding country during the recent re-survey of that district. Dr. Read has continued his work on the igneous and metamorphic rocks of Sutherlandshire, and Mr. A. G. MacGregor has continued his investigations of the lavas and intrusions of Ayrshire, carrying on the work he completed for the Memoir on Sheet 22 (Kilmarnock) into the area of Sheet 14 (Ayr).

Mr. Simpson has published a paper upon the lavas of the Faroë Islands, and Mr. MacGregor presented to the Geological Society of Glasgow an exhaustive paper that dealt with the classification of the Carboniferous basalts of Scotland.

Dr. Tyrrell, of Glasgow, has published as a Survey Memoir his revision of the petrography of Arran, and the volume forms a valuable companion to others dealing with the Tertiary province.

A large amount of interesting material, mainly from dykes, has been collected by the officers recently engaged upon the survey of the Orkney Islands, and the corresponding sections have been dealt with by the Director.

Material from the Shiant Isles has been presented by Dr. F. Walker, who is engaged in a petrographical study of these islands.

The number of sliced rock-specimens and corresponding sections registered in the collections and housed in the Petrographical Department in London is as follows :—

English and Welsh	14,471
Scottish	26,690
Irish	451
Foreign	2,770
Total	44,382

This represents an aggregate increase of 778 in the registered sliced specimens during the past year. Of the corresponding sections 738 were made in the London Office and 40 were registered for preparation in Scotland.

Photography

Mr. J. Rhodes has been employed in taking geological photographs and views, mainly in the districts of Gloucestershire, Devonshire, Northumberland, Lancashire and Yorkshire, to the number of 384.

The number of registered negatives is now as follows :—

English Photographs	4,603
Photomicrographs	1,895
Miscellaneous	1,869

Prints to the number of 1,433 have been made in the London office, chiefly for incorporation in the Survey albums in the London and Scottish offices.

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Mr. Rhodes has mounted 1,058 prints and 816 descriptive forms for use in the English and Scottish Survey Libraries and provincial offices.

The albums are now completed to the following registered numbers, each photograph being accompanied by its corresponding descriptive form :—

English Series	4,219
Scottish Series	3,095

Miss E. M. Lind Hendriks, under the supervision of the Director, has prepared a list of Classified Geological Photographs selected from the Survey albums for the use of lecturers and teachers and as suitable for the illustration of manuals of geology. About 2,500 of the most characteristic views have been chosen from the Survey collection, arranged under descriptive headings, and their localities and geological features have been briefly stated. This work is meant for a handbook to those who wish to consult the albums, which are now so large that it is difficult to search them for the best examples of geological structure and scenery. The book has been well received and numerous applications have reached us for copies both from European countries and from the United States and Canada.

Mr. Robert Lunn, who for many years took all the Scottish photographs for the Geological Survey, has completed a catalogue of our Scottish geological negatives arranged according to the Sheets of the one-inch geological map. This catalogue will be of much use as it enables us to find all the views from any particular district without elaborate search. It gives also particulars of the subject taken and of the quality of the negative. From this catalogue a card-catalogue has been made for the London office. Visitors to the library who wish to see geological views of any part of Scotland can find them easily through this means.

Chemistry

The number of rock-specimens registered in this department's books as analysed or for analysis at the end of 1928 is as follows :—

English	342
Scottish	510
Irish	2
Welsh	55
Others	46
Total	955

Of these, nineteen have been analysed during the year and eight are still in progress of analysis. Thirteen qualitative examinations have been carried out for Survey officers and many enquiries from other sources have received attention.

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Mr. R. Sutcliffe, M.A., A.I.C., was transferred on August 20th, 1928, to the Government Laboratory.

Museum of Practical Geology

In the Museum in London no important changes have been made during the year. No further defects have been discovered in the structure of the building and the temporary electric lighting installation continues in the same state as before. In view of the report of the Royal Commission on National Museums and Galleries and the steps taken last year to press the urgent necessity for a new building it has not seemed worth while to initiate changes of exhibits on any considerable scale. A new display of recently published one-inch maps has been put out in the entrance hall and the most striking accessions to the collections of minerals and gemstones are shown in special cases near the top of the main staircase. A large part of the Museum, however, is so dark that the specimens exhibited cannot be properly inspected unless they are taken out of the cases. The growing collections urgently require more room and everything that can be done to pack them more closely and utilize every cubic foot of space available has been tried. New iron racks of drawers for the fossil cabinets in the palaeontological rooms were being installed at the close of the year, and part of the old chemical laboratory was being adapted for use as a photographic room as required. The temporary roof continues to afford a sufficient protection against the weather though it leaks badly during rain, and the removal of the glass windows renders the interior of the building almost useless for the purpose for which it was constructed.

List of Donations during the year 1928

ADCOCK, C.P., ESQ.—Demantoid, cut and uncut, from Italy.

BRADLEY, R. W., ESQ.—Twelve pictures painted upon mica from India.

BURKE, E., ESQ.—A specimen of *Mantelliceras sp.* from the Chloritic Marl of Ventnor, Isle of Wight (collected during subsidence of July 1928).

COBBE, H. N. C., ESQ.—Telluride ore from Kalgoorlie.

DAVIES, W. J. & SONS, Ltd.—Chloritoid with corundum.

DAVISON, E. H., ESQ.—Veinstone showing wolfram changing to scheelite.

DRUGMAN, DR. J.—Quartz twins selected from material collected by Sir John Flett, K.B.E., F.R.S., etc.

EDMONDS, C., ESQ., J.P., F.G.S. (*per* Dr. B. Smith, M.A., F.G.S.).—A specimen of *Orionastraea ensifer* (Edwards and Haime) from the Carboniferous 4th Limestone (top of Potholes Limestone) of Clints Quarry, near Bigrigg, Cumberland.

FABER, OSCAR, ESQ., O.B.E., D.Sc., M.INST.C.E.—A specimen of *Nautilus* from the London Clay (in excavations for foundations) east of Marconi House, Aldwych, W.C.2.

FRANCK, S. M. & Co.—Artificial lapis beads.

GASTER, C. T. A., ESQ., F.G.S.—A series of specimens, including zonal forms of *Echinocorys*, from the Upper Chalk of Sussex.

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GLASSON, L., ESQ.—Large group of selenite crystals from Eden Valley, Cumberland.

GOODCHILD, DR. W.—Laumontite from Park Brow, Dockwray, Cumberland.

GREENLY, E., ESQ., D.Sc., F.G.S.—A series of specimens (seeds and marine shells) from the Pleistocene deposits of North Wales.

GREY, REV. J. C.—Limonite concretions from Dordogne, France.

GRIFFITH, PERCY, ESQ., M.INST.M.E., M.INST.C.E., F.G.S.—Two specimens of *Exogyra sinuata* (J. Sowerby), and an associated cluster of *Serpula sp.*, from the Tealby Beds between depths of 43-51 feet in well excavation at Skegness Water Works, Welton, Lincolnshire.

HAYES, DR. A. C.—Large block of iron ore from Wabana, Newfoundland.

HESTER, S. W., ESQ.—A series of specimens from the Upper Chalk (*Hyphantoceras reussianum* subzone) of Aston Hill, near Aston Rowant, Oxfordshire.

HOBLEY, C. W., ESQ., C.M.G.—A large series of fossils from the collection of the late N. T. Wetherell, including a series of London Clay shells collected from exposures no longer accessible; also a fine example of *Exogyra sinuata* (J. Sowerby) from the Lower Greensand (Hythe Beds) of Rag Quarry, near Alington Lock, Kent.

HORE, H. H. ESQ.—Two specimens of ancient slags from Ewhurst, Sussex.

ICHTHYOL, MESSRS, LTD.—Sample of the oil-shale from which 'Ichthyol' was prepared.

KHASIA SILLIMANITE SYNDICATE LTD.—see Swetenham, C.C., Esq.

LEACH, A. L., ESQ., F.G.S.—A small series of fossils from the Carboniferous Limestone (Upper Seminula Zone, S_2—near top) of Proud Giltar, near Tenby, South Pembrokeshire.

MACARTNEY, ROSS, ESQ.—Cassiterite and wolfram from Lower Burma.

MACGREGOR, M., ESQ., M.A.—Crystallised barytes from Leadhills, Scotland.

MARSH, MISS JOAN.—Curiously marked flint from Frinton, Essex.

MATLEY, C.A., ESQ., D.Sc., F.G.S.—A series of Ordovician fossils from the Lleyn Peninsula, Carnarvonshire. Eleven rocks and rock-sections from the Lleyn Peninsula. Also suites of rocks, mainly igneous, from the same district of Carnarvonshire.

MOORE, E. W. J., ESQ., B.Sc., A.I.C.—Specimens of *Dimorphoceras discrepans* (T. Brown), *Dimorphoceras gilbertsoni* (Phillips) and *Goniatites crenistria* Phillips, from the Bowland Shales of Pendle; and *Anthracoceras atratus* (Beyrich) from the Lower Coal Measures of Accrington, Lancashire.

NEWTON, E. T., ESQ., F.R.S., F.G.S.—A series of shells and fish-teeth from the Basement Bed of the London Clay at Ayot Green, near Welwyn, Hertfordshire, including *Odontaspis elegans* (Agassiz), *Odontaspis cuspidatus* (Agassiz), *Lamna vincenti* (Winkler) and *Phyllodus toliapicus* Agassiz, mentioned in *Proc. Geol. Assoc.*, vol. xix, p. 355, 1906.

PIZZALA, JOSEPH, ESQ.—Gypsum in centre of pyrite nodule.

POPE BARTLETT, BENJAMIN, ESQ., M.R.C.S., The Executors of the late.—The collection of Cretaceous fossils made by the late Dr. B. Pope-Bartlett, comprising about 1,500 specimens.

POPHAM, J. L., ESQ.—Specimens from a mining district of Venezuela.

RICHARDSON, L., ESQ., F.R.S.E., F.G.S.—A specimen of *Tulophorites* aff. *tulotus* S. Buckman, from the Great Oolite of Salperton, Gloucestershire.

RUSSELL, ARTHUR, ESQ.—Pennine from Chile.

SEDGWICK CLUB, THE, *per* W. B. R. KING, ESQ., O.B.E., M.A., F.G.S.—A series of specimens from the Ordovician, Silurian and Carboniferous rocks of the Oswestry District.

SMITH, DR. BERNARD, M.A., F.G.S.—Barytes from Bigrigg, Cumberland.

STAPLETON-COTTON, COLONEL.—Crystals of a chromium-bearing amphibole, from Norway.

STRAKER, E., ESQ.—Series of iron slags from Sussex.

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STYRIAN JADE LTD., MESSRS.—Bowl made of Styrian jade.

SWAN, CHARLES, ESQ.—Beryl burnt to resemble aquamarine.

SWETENHAM, C. C., ESQ. (*for* KHASIA SILLIMANITE SYNDICATE LTD.).—Sillimanite from Khasia Hills, Assam.

TULLY, B. J., ESQ., F.G.S.—Specimens of parisite and malachite, also cut specimens of cassiterite, tourmaline, hauyne and a garnet doublet.

WALKER, DR. F.—Additional suite of specimens, 17 in number, from the Shiant Isles.

WHITELEY, J. H., ESQ.—Tested silica bricks.

YOUNG, G. W., ESQ., F.G.S.—A series of specimens from the Chalk area of Western Surrey, illustrative of his paper in *Proc. Geol. Assoc.*, vol. xx, p. 422, 1908.

JOHN S. FLETT,
Director.

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II. DISTRICT REPORTS

(A)—ENGLAND AND WALES

1. SOUTHERN DISTRICT

HENRY DEWEY, District Geologist.
H. G. DINES, A.R.S.M., A.M.INST.C.E.
W. LLOYD, B.Sc.
F. H. EDMUNDS, M.A.
C. J. STUBBLEFIELD, B.Sc., A.R.C.Sc., PH.D., D.I.C.
} Geologists.

In the Southern District the survey of the Reigate map (Sheet 286) was commenced by Messrs. H. G. Dines and F. H. Edmunds. In the autumn Dr. Stubblefield joined the unit and was engaged in mapping a small area near Dorking. In the early spring Mr. F. H. Edmunds surveyed on the six-inch scale an area near Portsdown Hill between Purbrook and Hayling Island, while Mr. Dines completed the revision of the drift and some of the solid formations of the Cotswold Hills between Moreton in Marsh and Cheltenham, for the new one-inch Sheet 217.

Mr. Lloyd has continued the revision of the Torquay district for the new edition of the memoir (Sheet 350).

Mr. H. G. Dines and Dr. Robertson were specially delegated to make a mine survey of the old South Terras Uranium Mine and also of the Tolgarrick Mine, near Grampound Road, Cornwall, on behalf of the Special Committee on Radium Resources. The field work is complete, but no report can be issued until the assay analyses have been made.

Mr. Dewey's time has been mainly occupied with indoor work on editing the following maps and memoirs :—Aldershot (285), Sudbury (206), Dover (290) and Ramsgate (274), Hastings (320) and Dungeness (321), Moreton in Marsh (217), Windsor (269). In addition there has been an increasing number of enquiries relating to water-supply, soils, foundations for buildings and sites for tunnels, and upwards of 300 received attention. Mr. Dewey inspected the field-work of Mr. Edmunds in Hampshire and Surrey, and of Mr. Dines in Gloucestershire and Surrey, and also examined some gravel deposits on the Chilterns and at Bedford. Mr. Edmunds attended the Conference on Soil Surveys with the Ministry of Agriculture's representatives at Oxford.

REIGATE SHEET

Lower Greensand.—Mr. Dines has mapped a strike-fault with the downthrow south to which the outliers of Hythe Beds north-east and north-west of Nutfield Station owe their preservation. The

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maximum amount of throw appears to be at Lyttel Hall, where it is about 40 feet. The fault probably extends as far eastward as Tilburstow Hill.

The Sandgate Beds are only thinly developed at Reigate Park, but they cover more of the dip-slope of the Hythe Beds than is shown on the Old Series map Sheet 8.

The Folkestone Beds present an unusual feature of a bed of clay up to 10 feet thick in their higher parts. It has been noted by Mr. Gossling on the west at Buckland and on the east of Reigate in Apted's pit, north of Wray Common, and was recorded by Topley[1] in the road cutting at Tunnel Hill, Reigate, and north of Reigate Heath, but beyond these limits it has not been traced. At Buckland it is separated from the Gault by about 60 feet of coarse pebbly sand, and is underlain by fine white and yellow sand. At Tunnel Hill the coarse pebbly sand appears to be about 30 feet thick, while at Apted's pit the clay bed crops out immediately south of the Gault. Eastwards of Apted's pit the pebbly sand again underlies the Gault; this rather suggests a small local unconformity in the Folkestone Beds.

The **Gault** and the **Upper Greensand** and **Chalk.**—A dip-fault with the downthrow to the east extends from ½ mile east of Wray Common north-westwards. It dislocates the Gault, Upper Greensand and the Chalk, but the extent of the disturbance in the Chalk cannot be proved until the zones are determined.

Mr. Edmunds has surveyed an area of Gault, Upper Greensand and Chalk around Dorking, where the lower beds are affected by a monoclinal fold with an east to west axis. Between Leatherhead and Epsom the outcrop of Upper Chalk presents no unusual features.

Tertiary Beds.—Mr. Edmunds and Dr. Stubblefield note the occurrence of outliers of the Tertiary Beds consisting of Reading Beds and Thanet Sand near Headley, but only of Thanet Sand at Walton-on-the-Hill and Burgh Heath. The beds form one outlier at Nower Wood, Headley, and not two, as indicated on the old geological map.

Drift Deposits.—A wide tract around Horley has been observed by Mr. Dines to be covered locally with a remarkable deposit of gravel consisting of fragments of shale from the Weald Clay, and more or less cemented with ferruginous matter, set in a matrix of finely comminuted shale. This gravel is known locally as 'chevick.' It averages from 2 to 3 feet, but in some parts attains 8 feet, in thickness. A slightly loamy clay spreads over it to a depth of 2 to 3 feet, and as this clay is indistinguishable in surface exposures from the Weald Clay the boundary is very difficult to trace. The Weald Clay holds up water at the base of the chevick and numerous wells have been dug to obtain small supplies.

[1] 'Geology of the Weald' (*Mem. Geol. Surv.*), 1875, p. 141.

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In the survey of the area around Redhill and Reigate Mr. F. Gossling, a member of the Geologists' Association and of the Weald Research Committee, has rendered great help, and has kindly placed at the disposal of the Survey his detailed notes of temporary sections made during recent years. This information has materially assisted the work of drawing boundary lines, especially in town areas.

In Hampshire Mr. Edmunds records the existence of a widespread mass of chalky detritus, briefly described by Mr. H. J. O. White,[1] which marks the lower slopes of the Portsdown Hill and extends thence southwards to below sea-level. He also observed some high-dipping beds exposed in a road-cutting about a mile south of Purbrook, where the London Clay and the Reading Beds dip about 30 degrees north. The narrow outcrop of these beds is due to their high dip and not to abnormal thinness.

Torquay Sheet

Mr. Lloyd has examined numerous temporary trenches in Torquay, Paignton and Totnes, which show that it is impossible to subdivide the Permo-Triassic rocks into a definite sequence of clays, sandstones and conglomerates, for each may laterally replace the other.

Careful search has been made for fossils in the Lower Devonian rocks in order to ascertain if the correlation on broad lines put forward by Dr. Asselbergh,[2] of Belgium, could be substantiated in detail. While it may be safe to assume that the Gedinnien-Siegenien and Emsien are in part represented by the Dartmouth Slates, Meadfoot and Staddon Beds, yet the relative scarcity of fossiliferous horizons and the highly disturbed relations of the beds do not admit of the detailed application of the continental zones.

H. Dewey.

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[1] 'Geology of the Country near Fareham and Havant' (*Mem. Geol. Surv.*), 1913, p. 77.

[2] 'Correlation of the Meadfoot Beds with the Siegenien of the Ardennes,' *Geol. Mag.*, 1921, p. 165.

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2. MIDLANDS DISTRICT

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Except for a few points of detail, requiring further investigation, the revision on the six-inch scale of the area included in one-inch Sheet 152 (Shrewsbury) was completed during 1928. Mr. Pocock was working in the Severn Valley, between Cressage and Shrewsbury, including the districts of Pitchford, Condover, Berrington and Atcham. Mr. Whitehead's area lay to the south-west around Pulverbatch and Leebotwood, while Dr. Robertson's was to the south, between Harley and Longnor. A small area east of Westbury was mapped by Mr. Wedd, but for most of the year he was engaged on indoor map-work, and along with Mr. Dinham, on the preparation of memoirs for the press.

Pre-Cambrian.—Mr. Pocock finds that the Uriconian rocks of Charlton Hill, on the line of the Church Stretton fault-complex, consist mainly of ashes and conglomerates. The same rock-types occur at Brom Hill to the south and round Dryton. Uriconian ashes and conglomerates, traversed by basic igneous dykes, are also exposed in the south bank of the River Severn at Cound Lodge Inn, and in the adjoining railway cutting. Similar ashes crop out near Harnage House and in the valley of Cound Moor Brook near Stevenshill, where they are in faulted contact with the Harnage Shale.

Dr. Robertson's examination of the northern end of the Lawley hill, farther south-west, shows that the greater part of the Uriconian there consists of volcanic ashes, with some rhyolitic flows and several intrusions of dolerite. The Uriconian definitely extends for at least half a mile north-eastwards beyond the northern end of the hill. The Western Boundary Fault, which is the northward extension of the Church Stretton Fault, appears to have at least two components.

No attempt has been made to map separately the sub-divisions of the Eastern Longmyndian recognised by J. F. Blake[1] and C. Lapworth,[2] as this part of the sequence is particularly poorly exposed in the area surveyed by Mr. Whitehead. A line of division between the Eastern and Western Longmyndian has, however, been drawn with as much accuracy as the conditions permit. The line adopted corresponds with the 'base' (or eastern limit) of the Haughmond conglomerate, where this bed can be recognised. This is the easternmost of the three conglomerates distinguished by

[1] *Quart. Journ. Geol. Soc.*, vol. xlvi, 1890, p. 386.
[2] In 'Geology in the Field,' *Geol. Assoc.* Jubilee vol., 1910, p.746.

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Lapworth in the Bayston Group of the Western Longmyndian. On Smethcott Common and near the Betchcott (Batchcott) Hills, however, only two conglomerates have been found, and it appears that the Haughmond conglomerate must die out at some point north of the former locality. The peculiar micaceous grits associated with this conglomerate on Haughmond and Sharpstone Hills can, however, be recognised where the conglomerate itself appears to be absent. These grits are separated fairly sharply from the more shaly beds to the east of them, which have been relegated to the Eastern Longmyndian. Although some of the rocks to the east of it show affinities with the Western Longmyndian, the line of division chosen is the most practicable for the purposes of mapping, and it appears to correspond with that adopted by Lapworth.

The Western Longmyndian falls into three well-marked sub-groups to which the following names (in order from east to west) may provisionally be given :—

Bayston Group,[1] purple grits with conglomerates.

Bridges Group,[2] dark purple sandy shales with relatively fine-grained grits.

Oakswood Group,[3] red-purple grits with conglomerates.

The approximate limits of these sub-groups have been drawn on the map.

The Longmyndian rocks of Sharpstone Hill, south of Shrewsbury, continue north-eastwards, into Mr. Pocock's ground, the divisions observed by Mr. Whitehead at Bayston and Lyth Hills. The Haughmond, Darnford and Stanbach conglomerates of the Bayston Group are well developed, and in Sharpstone Quarry there is a fine exposure of the purple and green grits that lie between the first two of these.

South-east of Sutton Hall purple and grey flaggy shales are exposed in a small pit just east of the outcrop of the Haughmond conglomerate and, about 150 yards east of this pit, an exposure shows lavender sandstone and marl of Keele Beds type. The junction between the Keele and Longmyndian appears to be a fault. An exposure of grey Longmyndian flaggy shale with calcareous bands, about 100 yards in length, was found in the right bank of the River Severn on the line of this fault; this outcrop forms an interesting link between the Longmyndian rocks of Sharpstone Hill and those of Haughmond Hill.

The Longmyndian inlier at Pitchford has also been mapped. The rocks exposed consist of grey-green and purplish flags with some calcareous bands.

Cambrian.—Mr. Pocock has continued his examination of the Cambrian area of Rushton, between the Wrekin and Charlton Hill.

[1] Lapworth, C., *loc. cit.*

[2] From 'the Bridges' near Ratlinghope (Sheet 166).

[3] See 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), Pt. I, 1928, p. 40.

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Natural exposures are poor and infrequent and much of the ground is obscured by drift while, in addition, the difficulties of mapping are increased by the complex faulting.

The ground has been trenched at critical points, and numerous trial holes have been put down, from which sufficient information has been obtained to formulate a reasonable interpretation of at least a part of the sequence and to make it possible to map the boundaries of Lower, Middle and Upper Cambrian with some approach to accuracy.

A large number of fossils have been collected from various horizons and these are being examined and reported on by Mr. E. S. Cobbold. Until he has completed this work it will not be possible to discuss the sequence in detail. It can be said, however, that the presence, in place, of the several horizons recorded in last year's *Summary of Progress* has been confirmed by the trenching and trial holes.

The Cambrian rocks have been proved to extend round to the west side of Charlton Hill, where they are cut off by the main line of the Church Stretton fault.

Between the Lawley and Hoar Edge, though for the most part concealed under drift, both Lower and Upper Cambrian are definitely present in Dr. Robertson's ground, and it is hoped that further search will enable some subdivision of the latter to be made. The basal quartzite forms much of the western slope of the Lawley, as is also the case on Caradoc and the Wrekin.

Ordovician.—The base of the Ordovician in Dr. Robertson's area is the Hoar Edge Grit. It rests unconformably on the arenaceous beds at the top of the Shineton Shale sequence, and varies in thickness from less than 40 feet above Harnage Grange to 350-400 feet on Hoar Edge. North-east of Shadwell Coppice it is composed chiefly of flaggy calcareous sandstones with abundant fossils, but to the south it thickens rapidly by the introduction of sandy beds in which the calcareous facies practically dies out. The lower portion of the grit at Ruckley is very pebbly, and excellent examples of dreikanter were found in it there. The sand grains are in general rounded.

The Hoar Edge Grit is succeeded by the Harnage Shale, which usually forms low-lying drift-covered country, and is poorly exposed. It is some 1,000 feet in thickness in this area and is followed by the Glyptocrinus Flags and the Chatwall Sandstone, owing to the gradual introduction of more sandy sediment. The Chatwall Sandstone is very glauconitic in the neighbourhood of Chatwall. Towards the top of this sub-division fossiliferous bands appear, first of all with gasteropods, and later with brachiopods, forming the Alternata Limestone. Faulted outliers of all the groups from the Hoar Edge Grit to the Alternata Limestone occur in the Caradoc-Wrekin fault-zone around Acton Burnell and Coundmoor. Above

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the Alternata Limestone at Chatwall lie the Longville Flags, but these last are overstepped by the base of the Silurian south-west of Church Preen, and none of the higher beds of the Caradocian are present in this part of the sheet. An outline of the Caradocian succession in this area has already been given by C. Lapworth.[1]

Ordovician rocks are found also in Mr. Pocock's area, in thickly wooded ground near Harnage and Coundmoor Brook, where the Hoar Edge Grit and Harnage Shale are involved with Shineton Shale and Uriconian strata in a highly complex fault-belt.

Silurian.—Owing to paucity of relevant exposures, the thicknesses of the three local divisions of the Valentian can be estimated only roughly. The name Kenley Grit is suggested by Dr. Robertson for the arenaceous basement beds. An exposure of grey calcareous and sandy beds, associated with fragments of Pentamerus limestone in Bentleyford Brook, north of the Lawley, indicates the presence of the Pentamerus Group just west of the main line of the Church Stretton fault. The line between the Purple Shale Group and the Pentamerus Group has been drawn at the base of the beds actually characterised by the presence of purple and green shales, as this is the most satisfactory lithological horizon. It does not necessarily coincide with any line drawn on palaeontological grounds.[2]

Carboniferous.—The Coal Measures in the area surveyed by Mr. Whitehead are almost entirely concealed by superficial deposits. Some information concerning the collieries at Longden Common, including a plan giving the workings in one of them up to 1880, has been furnished by Mr. S. Fenn. It appears that only one coal was known in this district. The presence of a Spirorbis limestone is indicated by fragments found on one of the pit-banks. Of the Leebotwood Coalfield there is little to add to Murchison's account.[3] The principal pits were at Longnor. Three coals were known, identified with the Yard, Half Yard, and Thin Coals of the Pontesbury field. A Spirorbis limestone is present. One pit is situated about 150 yards east of the railway, some 600 yards south of a cutting in which Longmyndian shale is exposed. Judging from the size of the spoil bank this pit cannot be very shallow, and it would thus seem probable that the junction between the Coal Measures and the Longmyndian is a fault.

At Pitchford, within Mr. Pocock's area, the basement bed of the Coal Measures is composed, in places, of a breccia of Longmyndian shale fragments in a matrix of bituminous sand. Spirorbis limestone and a bed full of fossil wood occur in Row Brook near the base of the measures. Lower down the brook some red marl in the Keele Beds yielded a number of specimens of *Spirorbis* ; this appears to be the first record of this fossil from any marl in the Keele Beds.

[1] In 'Summary of Progress ' for 1915 (*Mem. Geol. Surv.*), 1916, p. 38.
[2] Whittard, W. F., *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 737.
[3] ' Silurian System,' 1839, p. 93.

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Dark bituminous Spirorbis limestone was also found, apparently near the base of the Keele Beds, a short distance north of the Longmyndian outcrop in the Severn River bank, north-east of Sharpstone Hill. There appears to be no evidence for the fault shown on the old map as running north-westward through Eaton Mascott between the Trias and Permian (Keele Beds).

An outlier of calcareous conglomerate resting on Keele Beds was found to form a capping to the high ground one mile south-west of Pitchford Hall. This conglomerate appears closely comparable to the Alberbury breccias and conglomerates, some 10 miles to the north-east, and forms an important connecting link with the Enville conglomerates.

Trias.—The outcrop of Pebble Beds, shown on the old map, east of Longnor Hall, near the Severn, should probably be referred to the Lower Mottled Sandstone.

Superficial.—Mr. Whitehead finds that the rather stiff boulder clay of the Habberley Valley and the valleys immediately to the east gives place, around Cothercott, Picklescott and Woolstaston, to lighter and more stony deposits. Around Smethcott and Woolstaston stony clays, clayey gravels and cleaner gravels shade off into one another laterally, but tend to map out as lenticles approximately following the contours of the ground. This suggests that the deposits, as a whole, are stratified, but bedding can seldom be discerned in the few sections available.

The clayey gravels of the Rea valley, referred to in the *Summary of Progress* for 1926,[1] appear to have their counterpart in similar gravels occupying flattish ground south of Bayston Hill. This flattish area is in continuity with a terrace, at about 300 feet above O.D., which between Condover and Stapleton is, on the average, between 30 and 40 feet above the flood plain of the Cound Brook. The tributaries that enter this brook from the west are bordered by areas which from side to side are almost flat, with a very gentle slope apparently graded to the level of the terrace. These flattish areas, though topographically very distinct, are occupied by stony clay and clayey gravel not readily distinguishable from the drifts of higher levels. In some cases the flat areas end, up stream, in a low terrace; and, in nearly every case, the valley closes in, at a height of about 500 above O.D., to form a steep-sided dingle with a flat bottom.

Moundy drift covers Mr. Pocock's ground round Berrington, Betton and Bomere. Esker-like ridges of sand and gravel form conspicuous features of the landscape, while meres and peat mosses occupy the hollows. The general trend of some of the ridges and hollows appears to be aligned with the gap in the Longmyndian ridge between Sharpstone and Bayston Hills.

[1] *Mem. Geol. Surv.*, 1927, p. 45.

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Strong glacial striae running north and south were observed on the surface of the Longmyndian grits at the top of Sharpstone Quarry, while at Charlton Hill the direction of the striae on the Uriconian rocks is to the south-south-east.

C. H. DINHAM.

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3. YORKSHIRE DISTRICT

Headquarters : York

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WILFRID EDWARDS, M.A. }

Early in the year Mr. G. V. Wilson left the Yorkshire staff for Scotland on promotion. Mr. Stephens was again lent for work in Orkney for three months. Much of Dr. Wray's time was taken up by work in the Concealed Coalfield taken over from Mr. Wilson. Though the amount of field work has thus been curtailed, the mapping of the area covered by the one-inch map Sheet 86 (Glossop) may now be regarded as complete. Mr. Bromehead and Dr. Wray have been engaged on the Coal Measures in the north-eastern part of the Sheet, Mr. Edwards and, in the later part of the season, Mr. Stephens on the Millstone Grits in the south. The succession of beds below the Kinderscout Grits has been worked out, though exposures of marine bands have not been found.

Now that the one-inch map has been completely surveyed a general view of the Millstone Grit succession becomes possible and local names for the various 'rocks' (grits, sandstones, flags, etc.) can be selected where necessary. The oldest strata exposed belong to the Shale Grit Series, which is seen to a thickness of 200 to 300 feet. It consists of grit and sandstones with frequent partings of sandy shale; these beds are exposed in the Saddleworth, Tame and other valleys on the west of the area, in Longdendale and over the high moorland south of Bleaklow (Hill). Separating these beds from the Kinderscout Grits are the Grindslow Shales, usually 300 to 350 feet, though sometimes less where the pebbly base of the Kinderscout Series has 'ravined' them: they are micaceous shales and mudstones with occasional bands of sandstone and grit. These shales contain a marine band from which fossils were collected long ago by Holroyd and Barnes from an exposure below Raven Stones in the Chew valley.[1] These fossils are preserved in the Manchester Museum and have recently been determined by Mr. J. W. Jackson as *Reticuloceras reticulatum* Bisat, type form. The bed is therefore the same as that found in the corresponding position in Sheet 77; unfortunately it is not now exposed, owing to fallen debris, and its exact position in the Grindslow Shales is not known. Farther south it is absent, as in Derbyshire. The term 'Grindslow Shales' has been used recently by Mr. Jackson for the beds between the Kinderscout Grit and the Shale Grit,[2] and for this area affords a closer definition than the 'Sabden Shales' used in Sheet 77.

[1] Holroyd, W. F., and J. Barnes, 'Rocks and Fossils of the Yoredale Series of the Marsden and Saddleworth Valleys,' *Trans. Manchester Geol. Soc.*, vol. xxiv, 1896, pp. 70-99.

[2] Jackson, J. W., 'Succession below the Kinder Scout in N. Derbyshire,' *Journ. Manchester Geol. Assoc.*, vol. i, 1927, pp. 15-32.

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The Kinderscout Series may attain a thickness of as much as 600 feet. It consists entirely of coarse pebbly grit with a number of shale partings; flaggy beds, however, occur locally. The lowest member is usually thick, sometimes up to 300 feet. In the uppermost shale parting Mr. Edwards finds a band of black shale with *Lingula* and lamellibranchs, the equivalent of the 'cf. *Allorisma* band' of Bisat[1]; this bed was found in many parts of the Huddersfield area by Dr. Wray and others, and is well developed in the Wessenden valley; but in the country immediately north of Crowden it appears to have died out.

Within a few feet of the top of the Kinderscout Grit is the marine band with *Reticuloceras reticulatum* mut. α, which is everywhere well developed and easily detected, as indeed are several of the succeeding bands; the cloughs which converge on Holme in the centre of the Sheet afforded Mr. Bisat his type sequence. Brachiopods and gastropods have been found in addition to the more abundant groups.

The succeeding measures up to the White Rock vary to some extent from those proved in the area to the north. A comparatively short distance above the mut. α bed is a sandstone followed immediately by a bed with mut. β; in Ramsden Clough the top surface of the sandstone is mammillated and the goniatites can be found in the shale occupying the hollows. This band appears to be the only one in this area containing mut. β and is presumably the same as the most persistent of those found in the Huddersfield district; the sandstone would then be a representative of the Readycon Dean Series or Scotland Flags. In the south-east the 'Rivelin Grit' of the original survey[2] appears to be partly on the same horizon.

For the next important rock the name 'Heyden Rock' is proposed; this is the 'main third Grit' of the district and has been called the Pule Hill Grit in the north-western part of the area. In the valley of the Heyden Brook, near the middle of the area, it is well exposed and has been largely worked, the 'old quarries' being marked on the one-inch map. Its exact position in the sequence of marine bands is here accurately defined, as there are good exposures of the mut. γ and mut. β bands above and below it respectively; the latter band contains a conspicuous layer of large limestone nodules containing uncrushed specimens of the zonal and other goniatites. The conditions of deposition of these nodules have been such as to allow of the formation of petroleum from the animals inhabiting the shells. Mr. Edwards has found a *Lingula* band in a shale parting in the Heyden Rock. The sequence of the overlying shales varies somewhat, but in many parts they contain a thin rib of sandstone, not exceeding 10 feet thick overlain immediately by a band with dwarf *Lingula*; some 20 feet higher is the mut. γ

[1] *Naturalist*, 1920, p. 350; 1921, pp. 9, 10.
[2] 'Geology of the Yorkshire Coalfield' (*Mem. Geol. Surv.*), 1878, p. 36.

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band which is often found to form the roof of a thin coal or smut. The succeeding shales are sandy and rapidly merge into the white Rock.

The White Rock is everywhere well developed and occupies large areas of moorland on either side of the Yorkshire and Cheshire boundary in the central area. The top is a ganister which is succeeded by the Upper Meltham Coal. The Lower Meltham Coal is not persistent; it occurs below the mut. γ band with a bed of ganister as its seat; both coal and ganister have been worked south of Meltham.

The normal sequence above the White Rock shows shales containing the Cancellatum and Cumbriense Bands followed by the pebbly Rough Rock. In last year's *Summary* it was pointed out (pp. 44, 45) that a sandstone occurs locally between the two marine bands on the high ground south of Meltham; this sandstone reappears in the country west of Langsett, but not elsewhere; it would seem that we are dealing with isolated sand banks formed at a time when mud was being deposited over the greater part of the area. An interesting point is the occurrence of *Carbonicola* bands in these shales. In recent borings in the Huddersfield area Dr. Wray has found one between the White Rock and the Cancellatum band; at Meanwood, near Leeds, Professor Gilligan has recorded the 'intercalation of a *Carbonicola* bed between two marine bands,' presumably those of Cancellatum and Cumbriense[1]; Mr. Edwards has now detected a third lying between the Cumbriense band and the Rough Rock in surface exposures near Langsett. These occurrences confirm the conclusion already drawn from the goniatites that the Lower Coal Measures should on palaeontological lines be extended downwards to the top of the White Rock instead of the top of the Rough Rock.

The remaining part of the sequence of strata exposed in the area of Sheet 86 (Glossop) calls for no special comment here. Mr. Bromehead and Dr. Wray have mapped beds up to the Parkgate Coal in the Denby Dale and Cawthorne area, where the *Carbonicola* band in the roof of the Wheatley Lime Coal forms a useful guide.

A large number of photographs has been taken by Mr. Rhodes in the area of Sheet 86; enlargements of a few of these, together with specimen maps, etc., were exhibited at the annual meeting of the Yorkshire Naturalists' Union held at York in December.

C. N. BROMEHEAD.

[1] *Trans. Leeds Geol. Assoc.*, pt. xviii, 1920, p. 16.

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4. LANCASHIRE DISTRICT

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In Lancashire Sheet 85 (Manchester), the standardization of the six-inch maps has been completed, and these maps are now being published, while the preparation of the one-inch map is well advanced. A descriptive memoir of this area is now being written.

Several underground tunnels in metals below and above the Roger Mine in the Oldham area have been examined and collections from the fossiliferous horizons have been made by Mr. Hester. Examination of the fossils from these beds has afforded an effective correlation throughout this particular district, which confirms approximately but not in all detail the interpretation given in the mining records. The band between the Roger and Furnace Mines is known to some of the collieries as an index horizon. It yields *Anthracomya pulchra* in abundance.

In Sheet 84 mapping has been carried on throughout the summer on the Coal Measures of Wigan and St. Helens. Exposures are few, the ground being for the most part thickly covered by drift, and, until the available mining information is sifted, few conclusions can be drawn as to correlation or structure. A great diversity of nomenclature, combined with the fact that the same name is not infrequently applied to different seams, makes comparison with known areas difficult in the early stages of the work. This difficulty has been experienced by Dr. Sherlock in the St. Helens area, where all the coals have local names, the easily identified Arley Mine being for instance known as the Little Delf. The King Mine of St. Helens is identical with the Rushy Park Mine and is much lower in the succession than the King Mine of Wigan. Some of the seams such as the Sir John Mine may be local and without equivalent beyond the district.

Coal mining has been carried on around St. Helens during a long period and there are many worked out mines. The active collieries are for the most part situated along the southern margin of the exposed coalfield or under the Trias beyond. The wedge of Trias faulted down between Thatto Heath and Prescot suggests possibilities of reserves which, so far, have not been fully prospected.

In the Upholland area, where Mr. Tonks has been working, the succession above the Lower Mountain Mine appears to be very much expanded in comparison with that of the Rossendale area. The Lower Mountain Mine is got for coking at a colliery near Upholland Station and crops in the railway cutting west of the Upholland

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Tunnel. In the cutting a hard siliceous sandstone, strongly reminiscent of the Ganister Rock of the Bacup area, lies below the Lower Mountain Mine, and is about 100 feet thick. The shales above the Lower Mountain contain *Carbonicola* and pass up into shaly sandstone; the Bullion Mine Rock, with the Upper Foot Mine and its marine band is visible at the end of the section.

The shales below the Orrell Five Foot Mine (Three Quarters or Smith Mine) are worked for brickmaking near Orrell Station, and the *Carbonicola* band which occurs about 60 feet below the Three Quarters Mine in the Atherton area has been found in a drain leading from the brickyard to a culvert under the railway.

Glacial striae have been observed on the surface of the massive fine grained sandstone, Old Lawrence Rock, which is extensively quarried at Appley Bridge. Several striated surfaces are visible south of the Appley Road quarry on the west side of Appley Lane, 350 yards north-west of Appley Bridge Station. The most numerous striations run E.12°S., but there are others which vary in direction between E.18°N. and E.20°S.

Mapping has been continued by Mr. Jones in Sheet 84 (Wigan), where the greater part of the area between Horwich, Wigan and Leigh is found to be drift covered. Boulder-clay predominates, particularly to the west and north-west of Leigh.

Exposures of the Coal Measures are confined to the valley of the River Douglas as far south as Wigan, and to the high ground about Haigh and to the south of Standish. The sections along the Douglas figured by Hull[1] are now almost completely obscured.

In a disused brick-pit beside the railway about 1 mile north-east of Red Rock Station a remarkable strike section is visible. Dark blue shale with thin ironstone bands is seen to cut across the underlying blue-grey mudstone and an 8 ft. bed of flaggy sandstone with an unconformable junction. The line of this junction is clean and sharp and forms an angle of about 5° with the strike of the beds below. No discordance in the amount of dip has been observed.

Considerable spreads of sand and gravel have been mapped to the west and south of Adlington and are well exposed in sand-pits about ½ mile west of the church. Here the sand is overlain by 3 ft. of stony red boulder-clay. Another large area of sand occurs to the north and east of Wigan and extends up to Standish, and on the east side of the river Douglas below Haigh Park. The relations to the boulder-clay are not so clear in this area. Sands north of Hindley, which extend to the east to beyond Daisy Hill, are seen to pass below boulder-clay to the south.

W. B. WRIGHT.

[1] 'The Geology of the Country around Wigan' (*Mem. Geol. Surv.*), 1862.

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5. CUMBRIAN DISTRICT

Headquarters: London

BERNARD SMITH, M.A., Sc.D., District Geologist.
E. E. L. DIXON, A.R.C.Sc., B.Sc.
T. EASTWOOD, A.R.C.Sc. } Senior Geologists.
F. M. TROTTER, M.Sc.
S. E. HOLLINGWORTH, M.A., B.Sc. } Geologists.

The re-survey of Sheets 22 (Maryport) and 18 (Brampton) being completed, work was commenced on the northern margin of the Lake District north and east of Cockermouth (Sheet 23) by Messrs. Eastwood, Trotter and Hollingworth during a short field-season in 1928. The first-named studied part of the coalfield near Aspatria and the Carboniferous Limestone in the neighbourhood of Wardhall and Bothel as well as Skiddaw Slates south-east of Bothel; whilst the two latter, working in the central and east-central parts of the district near Uldale and south of Caldbeck respectively, grappled with the Borrowdale-Skiddaw Slate-Carrock Fell sequence and part of the succeeding Carboniferous Limestone Series.

Useful information about the volcanic and intrusive rocks has been obtained from this preliminary study, but further results must await the microscopic examination of the large number of rock specimens collected and those which will be secured in future, and also the correlation of the incomplete sequences determined at different points along the outcrop.

Skiddaw Slates.—Mr. Eastwood reports that in the area south-east of Bothel the general strike of the upper part of the Skiddaw Slates—in spite of many variations—is about east-north-east to west-south-west and the dip northerly. Hard sandstones, referred to the Watch Hill Grits,[1] occur in Blumer Beck east of Sunderland. These are succeeded by alternations of pale and dark mudstones which pass up into striped grey sandy shales with nodules and thin bands of hard fine sandstone. Farther east, near Bridgfield, west of Overwater, Mr. Trotter finds that the Skiddaw Slates pass conformably upwards into the Borrowdale Volcanic Series.

In the Caldbeck Fells the lowest beds mapped by Mr. Hollingworth belong to the Skiddaw Slates. No fossils have been found in them as yet, but their lithology and position suggest that they represent the higher beds of the series, being similar in type to the Mosser Slates of West Cumberland.[2] They have been studied principally around Great Sca Fell, where they lie in closely packed isoclinal folds. Grits of Watch Hill type form the top of Great Sca Fell, Little Sca Fell and adjoining heights, and have been proved to extend considerably to the north of their previously known limits.

[1] 'Summary of Progress' for 1924 (*Mem. Geol. Surv.*), 1925, p. 71.
[2] *Ibid.*, p. 71.

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Their exact relationship to the contiguous ' slate ' has not yet been determined. To the north the Skiddaw Slates are succeeded by Borrowdale volcanics.

Borrowdale Volcanic Series.—In the greater part of the ground examined by Mr. Eastwood the Borrowdale volcanic rocks are absent by pre-Carboniferous denudation, but at Bothel Craggs, farther east, porphyritic lavas of ' Eycott type,' associated with fine grained lavas and coarse tuffs, make their appearance. Still farther east the Borrowdale rocks appear in strength and have been mapped by Mr. Trotter between Binsey and Longlands Fell. The rocks here are uncleaved, and reliable dips, invariably at a steep angle to the north, were obtained ; so that a definite, although incomplete, sequence was recognised. It comprises a succession of andesites and tuffs which has proved to be identical to that recently made out independently by Mr. T. C. Nicholas.[1]

A lava approximately 15 feet in thickness, identical in hand specimens to the bytownite-bearing lavas of Eycott Hill, is the lowest horizon definitely occurring within the volcanic sequence ; but a shale breccia, displaying sedimentary banding, which underlies the lava and is faulted against the normal Skiddaw Slates, may prove to be a tuff. A second ' Eycott-type ' lava is separated from that above mentioned by a normal andesite sandwiched between two bands of shale of Skiddaw Slate type (each tuffaceous near its base), and is overlain by two belts of tuff parted by a dark-blue flinty lava of variable thickness. The upper tuff is followed by a group of normal green andesites, with occasional phenocrysts of augite, which appears to lie below a group of ' Eycott-type ' lavas, succeeded in turn by normal andesites.

The lower beds of the series are well exposed in the reservoir section north-east of Overwater and in the neighbourhood of Scawthwaite. Higher beds appear in the stream sections on Binsey and Longlands Fell.

In the ground mapped by Mr. Hollingworth, farther east, the exact relationships of the Skiddaw Slates to the Volcanic Series are obscure, but in the latter there appears to be a general upward sequence northwards. The lowest beds apparent form a group of green tuffs, with scattered fragments of pinkish felsite, associated with porphyritic augite andesite lavas. In the Dale Beck region a great thickness of fine-grained massive bluish andesites forms the crags west of the old Roughton Gill Mine. Their relations to the tuffs are rather obscure. They are followed by vesicular and fine-grained greenish andesites, succeeded by a well marked group of lavas indistinguishable in the field from the coarsely porphyritic lavas of the Eycott Hill-Berrier region lying to the south-east. Associated with these are fine-grained andesitic types and pinkish

[1]Mr. Nicholas not only generously communicated some of the results of his unpublished work, but also spent several days in the field with Mr. Trotter or other members of the unit.

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rather acid looking rocks, the margins of which locally suggest intrusive relationship. Observable dips are scarce in these rocks, weathered outcrops, which might exhibit banding or bedding, being practically non-existent.

Dark-bluish compact and greenish vesicular andesites in some variety occupy a belt of country north of the 'Eycott' types. These in turn are succeeded by a group of tuffs, frequently quite coarse in texture. Acid fragments of a pale silver-grey colour are a characteristic feature of this group, which, when traced westward, is cut out by the overstep of the Basement Beds of the Carboniferous Limestone Series.

Intrusions.—Small areas of the western part of the Carrock Fell intrusive complex have been mapped by Mr. Hollingworth about the head of Roughton Gill. Part of this ground had been included previously in the Borrowdale Volcanic Series. A deposit of china-clay, which was once worked to a small extent north of Great Lingy Hill, lies on the northern margin of the intrusive complex and may be related to it. Kaolinization is widespread in the immediate neighbourhood.

A number of small dykes, frequently associated with basic material so as to form composite intrusions, pierce the lower part of the crags west of Roughton Gill Mine. They have an east and west trend and die out upwards. In hand specimens their appearance suggests an origin from the Carrock Fell complex—or, in view of their trend, a derivation from an underground extension of that magma.

Carboniferous Basement Beds.—The basement beds, of supposedly Carboniferous age, which underlie the Cockermouth Lavas in the western part of the district,[1] are represented also in the areas mapped by Messrs. Trotter and Hollingworth, but the overlying lavas appear to be wanting. Exposures in stream and ditch sections examined by Mr. Trotter prove that a large drift-covered area south of Uldale, previously considered to be underlain by volcanic rocks, is really occupied by red and green marls (or shales) with conglomerates.[2] Mr. Hollingworth finds the same state of affairs farther to the east.

Carboniferous Limestone Series.—From Sunderland westward to Wardhall Common the ground is occupied by part of the Carboniferous Limestone Series, largely masked by Glacial drift. The West Cumberland sequence from the 7th to the 1st Limestone has been recognised by Mr. Eastwood, but much further work remains to be done here owing to numerous faults. Quarries and trial holes around Wardhall, exposing limestones from the 1st to

[1] Eastwood, T., 'The Cockermouth Lavas, Cumberland,' 'Summary of Progress' for 1927 (*Mem. Geol. Surv.*), Pt. II, 1928, p. 16.

[2] Recognised by Mr. K. W. Earle, 'The Lower Carboniferous Rocks of Cumberland,' *Geol. Mag.*, 1922, p. 525.

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below the Girvanella Band[1] (base of D_2) near the bottom of the 4th Limestone, show that the limestones are here more widely separated than in West Cumberland. The Orebank Sandstone Series, which is considerably thicker, consists largely of shale, while a fairly thick belt of sandstone intervenes between the 3rd Limestone and the Junceum Beds and may be responsible for the absence of the 'Chert Beds' usually found at the top of the 4th Limestone. The latter, again, is more definitely split up by belts of shale and sandstone. It is noteworthy that a double coal, with a parting containing large Productids, which occurs at the base of the Junceum Beds at Broughton Craggs near Cockermouth, is present in the same position at Wardhall.

Near Udale a small area of the Limestone Series has been mapped by Mr. Trotter, who recognises both the Upper and Lower Dibunophyllum Zones; whilst the upper part of the Upper Seminula Zone (S_2) is probably present immediately above the Basement Beds. Here also the sequence is considerably thicker than in West Cumberland owing to the incoming of several beds of sandstone.

Limestones of D_1 age were examined by Mr. Hollingworth in a number of small quarries east of Nether Row. Lithologically they are strikingly similar to beds of that age both in the Pennines and in the ground studied by Mr. Eastwood.

Coal Measures.—The Coal Measures studied by Mr. Eastwood present no novel features beyond the fact that the deterioration of the Main Band, which sets in about Bulgill, is further accentuated in the Aspatria area, with the result that the Cannel and Metal Bands (parts of the split Main Band) are worthless. Many of the other seams also deteriorate in this direction; the Yard Band, on the other hand, improves and becomes an excellent seam.

Glacial.—The composition of the boulder clay and outwash moraines in the Ellen Valley and the trend of the drumlins indicate that a glacier from the northern slopes of Skiddaw filled this depression. Deltas and overflow channels noted by Mr. Trotter indicate that a glacier lake at 500 ft. O.D. occupied the Ellen Valley near Ireby during the recession of the ice after the Ellen glacier had split off from the main ice sheet to the north.

BERNARD SMITH.

[1] The position of this band was pointed out to us by Mr. C. Edmonds, of Moor Row.

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6. NORTHUMBERLAND AND DURHAM DISTRICT

Headquarters : Newcastle-on-Tyne.

R. G. CARRUTHERS, District Geologist.
G. A. BURNETT, B.Sc.
A. FOWLER, M.A., B.Sc.
W. ANDERSON, M.Sc.
} Geologists.

During the past year most of the Newcastle staff were engaged on office work, Mr. Anderson being the only one stationed in the field. He revised the north-eastern part of Sheet 8 (Elsdon), round Harbottle, Holystone, and Hepple. Much interest attaches to the development of the Scremerston Coal Group hereabouts; marine limestones begin to appear in fair number, as opposed to their rarity in more northern areas; the whole assemblage takes on an increasingly marine facies, in conformity with the change known to set in towards the Pennines.

Several bores and sinkings were examined during the year, notes on the more important being appended.

Tuedian.—The Cementstone Group along the Coquet valley shows one or two abnormally thick limestones, in continuation with those already noted towards Rothbury; the old quarries at Hetchester were in a bed quite 15 feet thick. In the burn below Whitefield House, south of the great Swindon Fault, the second limestone below the Fell Sandstone has a well-marked band of *Ortonella* concretions; this seems to be a widespread horizon in the north-west of Northumberland, and may be the equivalent of that noted by Professor Garwood as marking the base of the *Seminula gregaria* sub-zone in Ravenstonedale.[1]

The Fell Sandstone is responsible for much high, craggy ground south and west of Harbottle. There is lenticular bedding on a large scale amongst the coarse grits of this series, along with much repetition by east-north-east step-faults.

Scremerston Coals.—This series is prominent on either side of the Grasslees Burn, north of the Swindon Fault. Two coals have been wrought there, each reported to be 3 feet thick: the lower one (possibly equivalent to the Plashetts Coal) can be followed for many miles to the north-west, being repeated by step-faulting at Headshope and Wilkwood East. Below these coals, and only about 100 feet above the top of the Fell Sandstone, fossiliferous shales have been noted in the stream south of Swindon. A layer rich in crinoid debris and small ribbed shells, along with bryozoa, is found there. Over this some dark shales have yielded *Sphenopteris filiformis* Kidst., *Diplotmema patentissimum* (Ettingshausen) and other genera,

[1] Garwood, Prof. E. J., *Proc. Geol. Assoc.*, vol. xxvii, part i, 1916, pp. 1-10 and p ate 18.

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identified by Mr. Burnett. This discovery is of value, owing to the extreme rarity of identifiable plant-remains among Scremerston strata in general. Furthermore the crinoid bed shows that marine intercalations are present in this area at a very low level in the series: above the two coals they appear in stronger force, eight or nine limestones being found, from the Redesdale Limestone upwards; one of them (the Fourlaws Limestone) has a well-known workable coal above it. None of these limestones can be correlated with the Dun, which elsewhere marks the upper limit of the Group. Perhaps all of them may eventually be included within the Scremerston measures, but until more work is done this point must remain unsettled.

Glacial.—The later movement of the ice-sheet over the Harbottle area was east-north-east, and there are striae in this direction on Harbottle Hill. On its retreat this 'western ice' seems to have initiated, as a lateral feature, the gorge of the Coquet at Barrow Scars. Originally the river took a winding course round the foot of Calf Lee and Barrow Hill, now occupied by relatively unimportant streams. There was another diversion, of much smaller size, from the south to the north side of Harbottle village.

In addition to his field work, Mr. Anderson examined two deep borings put down by Synthetic Ammonia and Nitrates, Ltd., about one mile east of Billingham. Under nearly 100 ft. of drift, red Triassic sandstones predominated down to 400 ft., followed by 240 feet of red marl with occasional bands of sandstone and gypsum. Beneath came massive anhydrite, with subordinate beds of red marl and gypsum, the whole resting conformably on Magnesian Limestone. The junction of the Limestone (a buff-coloured, compact dolomite) with the anhydrite was examined both in the bores and in the two shafts completed in 1927: in all cases the passage downwards was gradual, the anhydrite being increasingly interleaved with bands of fibrous gypsum and well-bedded dolomite until the latter alone was present. In this dolomite are innumerable tubes of *Filograna* (?) *permiana* King, and occasional examples of *Mytilus squamosus* J. de C. Sowerby, *M. septifer* King, and *Schizodus schlotheimi* (Geinitz).

In the Coal Measures, Mr. Fowler has reported on a shaft recently completed at Lynemouth, near Ashington. The drift cover (65 feet) is heavy and rests on a 10-fathom bed of sandstone, much quarried round Woodhorn. At 80 fathoms the High Main Coal was reached and 7 fathoms above this was a band of estuarine lamellibranchs, well known elsewhere in the Ashington field.

Mr. Burnett dealt with the important sinking at Seaham Harbour, Co. Durham, which was completed early in the year. The two shafts passed through 420 feet of Magnesian Limestone, with 51 feet of yellow sands beneath: freezing was necessary here. The underlying Coal Measures had at least eight workable coals, ranging down

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to the Hutton seam. Plants, all of Yorkian facies, were got at many levels. The Low Main roof was rich in *Calamites*, but though fern-like plants were noticed at intervals, no band seemed to be of diagnostic value. There were several 'black bat' horizons, rich in *Carbonicola*: it is possible that some may be of value when our knowledge of the district is more complete.

A pipe-line recently cut down Benwell Bank, Newcastle, showed indurated and strongly reddened sandstones, broken and freely jointed, with partings of red shale, the whole resting directly on a 4-ft. coal, bituminous and unburnt. The alteration of the roof strata evidently dated from the great fire in the High Main Coal, known to have occurred hereabouts over two hundred years ago. A mile to the north there is a complete section of the High Main, 8 feet thick, in a clay-pit. The upper 4 feet is of distinctly better quality than that below, and it would seem that this upper part alone was wrought on Benwell Bank, the burnt-out galleries eventually collapsing on to the 'pavement coal,' kept cool by air passing inwards.

R. G. CARRUTHERS.

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(B)—SCOTLAND

1. AYRSHIRE

E. B. Bailey, M.C., B.A., District Geologist.
V. A. Eyles, B.Sc.
J. B. Simpson, B.Sc.
W. Q. Kennedy, B.Sc.
} Geologists.

Owing to pressure of indoor work only a small area near New Cumnock, in one-inch Sheet 15, was revised. Attention was limited to Carboniferous rocks and neighbouring outcrops of Upper Old Red Sandstone. Mr. Simpson worked in two areas, one south of the Nith at New Cumnock and the other near Dalblair on the Glenmore Water. Mr. Eyles mapped in the intervening district north of New Cumnock. Mr. Kennedy was only available for a very short time.

Calciferous Sandstone Series.—On Sheet 15 (Sanquhar) an elongated strip of 'intrusive doleritic rock,' ¾ mile long, is shown outcropping about 3 miles north-north-east of New Cumnock. Only two exposures occur, one in a stream running north to join the Glenmore Water a little west of Dalblair, the other one-third of a mile to the east-south-east, in a small disused quarry. At the former locality olivine-basalt of Dalmeny type is exposed along the stream bed for some 200 yards, and the outcrop appears to include at least two lava flows. The top of the lower of these is vesicular, with sediment bedded into cracks and cavities, leaving no room for doubt that it is in fact a lava flow and not an intrusion. The basalt in the quarry is of similar type to that of the stream. None of the known intrusive rocks of the district is of this type, and there seems no doubt that the quarry exposure is a continuation of the lava horizon. No other exposures of Calciferous Sandstone lava have yet been met with in this district, and it is uncertain whether this volcanic horizon is continuous with that which occurs farther north near Airds Moss.

Lower Limestone Group.—Two miles south-south-west of New Cumnock, in the Connel Burn, a limestone is exposed, which has been hitherto placed at the top of the Carboniferous Limestone Series. The presence in it, however, of *Productus giganteus* (Mart.) points to its being a member of the Lower Limestone Group, or of the top part of the Calciferous Sandstone Series. Coal Measures come on a short distance to the north, and it is clear that they must be separated from this limestone by a powerful fault cutting out most of the Limestone Coal Group, the Upper Limestone Group, the Millstone Grit, and a part of the Coal Measures. The direction of this fault is north-east, but it is nowhere exposed at the surface in the area surveyed.

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Upper Limestone Group.—The Index Limestone, characterised by the presence of abundant *Productus latissimus* J. Sow., has been recognised in two localities in the New Cumnock district. The first of these lies south of the River Nith, in Redree Burn, about 300 yards south of the farm of High Polquhirter. North of the river Nith the same limestone may be seen in the stream bank immediately to the east of Mansfield House.

Coal Measures.—Exposures of this group are scanty, but we are indebted to the New Cumnock Colliery Company for kindly supplying us with many valuable mining and boring records. A study of these has revealed the fact that the Productive Coal Measures of this area have a thickness of about 215 fathoms.

E. B. BAILEY.

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2. LANARKSHIRE AND PEEBLESSHIRE

J. E. RICHEY, M.C., B.A., District Geologist.
H. H. READ, D.Sc., A.R.C.Sc. } Senior Geologists.
J. PHEMISTER, M.A., D.Sc. }
G. ROSS, B.Sc. } Geologists.
W. Q. KENNEDY, B.Sc. }

In southern Lanarkshire (Sheet 15), the mapping of the Douglas Coalfield has been completed by Mr. Ross, and the memoir is in preparation.

In Peeblesshire (Sheet 24), the revision of the pre-Carboniferous Limestone rocks has been nearly completed by Drs. Read and Phemister and Mr. Kennedy. Some re-mapping of the Carboniferous Limestone strata that extend southwards into Sheet 24 from the Midlothian Basin (Sheet 32) was carried out by Mr. Richey, who also visited various Midlothian sections in connexion with the preparation of a new colour-printed edition of Sheet 32.

Dr. Read and Mr. Kennedy supply the following account of their work in the West Linton district of Peeblesshire.

Old Red Sandstone.—The north-easterly thinning of the Lower Old Red Sandstone lavas of the Biggar Centre, noted around Dolphinton,[1] continues into the West Linton district. Here, the great flow of acid lava that forms Black Mount, Dolphinton, is represented by a thinner development making up the ridge that ends in Mendick Hill. Farther north-east, the acid flow occurs as a narrow belt in the West Water at North Slipperfield. In the same burn, due north of South Slipperfield, a thin flow of amygdaloidal andesite is found. This and the North Slipperfield rock are alone left to represent the great lava-pile of the Biggar district. In the Lyne Water, between the Pentland Fault and West Linton, there are conglomerates, grits and sandstones, together with an extensive development of yellow-weathering 'claystones' that appear to be brecciated rhyolitic flows.

North-west of the Pentland Fault, in the upper valleys of the Lyne and West Waters, the southern part of the Lower Old Red Sandstone of the Pentland Hills is represented by sediments with quite subordinate lavas. These rocks are covered unconformably by friable, bright red sandstones belonging to the Upper Old Red Sandstone, of which the ridges of Catstone Hill, Fadden Hill and Craigengar, and the north part of Byrehope Mount, are composed. Like the volcanic rocks of the Biggar Centre, the lavas of the upper parts of the Lyne and West Waters decrease in importance towards the north-east. Thus, in the West Water there are possibly a dozen fairly thick flows, whilst to the north-east, in the Lyne Water, lavas

[1] Read, H. H., in 'Summary of Progress' for 1925 (*Mem. Geol. Surv.*), 1926, p. 107.

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are limited to a narrow zone next the Pentland Fault. Among the sedimentary rocks, a characteristic type is a coarse purple sandstone with very large plates of white mica. Conglomerates and greenish pebbly sandstone occur throughout.

In the Lower Old Red Sandstone of this part of the Pentland Hills thin sills of microdiorite are frequent, and are usually intrusive into conglomerate. A good example of a tapering sill is seen in the Lyne Water just below Cairnmuir (Baddinsgill).

Pleistocene.—In a sand-pit immediately north of Baddinsgill laminated clays rest on false-bedded sand and are overlain by sands and gravels. Traces of the same group of clays have been noted lower down the Lyne Water nearly to Wakefield, where they rest on boulder-clay. These clays, and the associated sands and gravels, are connected with the retreat-stage of the local glaciers.

J. E. RICHEY.

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3. FIFE AND KINROSS

J. E. RICHEY, M.C., B.A., District Geologist.
D. HALDANE, B.Sc.
J. K. ALLAN, M.A., B.Sc. } Geologists.
J. KNOX, B.Sc.

During the past year, Messrs. Haldane and Allan have been almost entirely engaged in office work in connexion with the Fife Coalfield. Mr. Knox, on returning from Orkney, continued his survey of the Dysart area northwards to beyond Leslie and Cadham, and supplies the report given below. The geological structure is much obscured by extensive spreads of sand and gravel and boulder-clay, often of considerable thickness. Rock-exposures are infrequent, and usually consist of dolerite sills intruded into sediments of Lower Limestone and Limestone Coal Group age. In this difficult area boring information has proved of value.

Lower Limestone Group.—In a quarry near the farm of Stenton, 2 miles south-east of Leslie, a hard, dark limestone, containing productids, crinoid stems, and corals, is seen dipping steeply to the west and north-west. The total thickness of limestone exposed is about 12 feet. In the Geological Survey Memoir on Central and Western Fife,[1] it is referred to as the Levenseat Limestone, and appears as such on the published map[2] of the district. Recent boring information has, however, thrown considerable doubt upon this correlation, and a consideration of the probable structure strongly suggests a horizon in the Lower Limestone Group rather than the Upper. Fossil evidence, though scanty, supports this view. One specimen of a coral collected from this limestone has been determined by Mr. Pringle as *Aulophyllum sp.*, a genus which is recorded in the memoir above referred to as having been obtained from only four Fifeshire localities, from strata of Lower Limestone Group age, three being from the Charlestown Main Limestone.[3] The available information, therefore, is considered sufficient to correlate the seam at Stenton with the Charlestown Main Limestone.

The above correlation necessitates the introduction of a powerful east-west fault passing immediately south of the quarry at Stenton, in order to bring in the Upper Limestone Group to the south. The existence of this fault is also indicated by bores, and it appears probable that to the east of Stenton the fault assumes a north-easterly direction, passing beneath the south end of Markinch to become continuous with the large east-west dislocation which has long been known to separate the Coal Measures of the Balgonie Basin to the south from the Carboniferous Limestone Series beneath Markinch and Star to the north.

[1] Geikie, Sir A., 'The Geology of Central and Western Fife and Kinross' (*Mem. Geol. Surv.*), 1900, p. 135.
[2] Geological One-inch Map of Scotland, Sheet 40, 1898.
[3] *Op. cit.*, p. 221.

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Limestone outcrops at Balgeddie and Pitkevy have also been investigated. At the disused Rothes Lime Works, 150 yards south-west of Balgeddie farm, and about half a mile north of Leslie, the following section is exposed in the eastern bank of the Lothrie Burn.

	Ft.	In.
Fakes and faky blaes		
Sandstone, brown, faky	2	0
Blaes, dark blue, mostly barren, lowest 3 in. abundantly fossiliferous (crinoid stems, brachiopods, lamellibranchs, trilobites, etc.)	24	0
Limestone, hard, dark, upper half almost barren, lower half full of crinoid stems	1	2
Limestone, hard, bluish-grey, upper 9 in. crinoidal and with a few shell fragments, lowest 6 in. darker, impure, with a few crinoid stems ...	2	0
Limestone, brown, sandy (base not seen)	1	6

At the top of the river bank and lying some 20 feet above the brown faky sandstone, the base of a dolerite sill is seen.

At Pitkevy, about three-quarters of a mile north-west of the above exposure, there is an old limestone quarry, now completely overgrown, but a south-easterly dip of the strata in this vicinity is indicated by an exposure less than 100 yards south-east of the quarry, in the east bank of a small ravine. There, sandy shales, slightly baked, are seen dipping below fine-grained dolerite. In the memoir already cited,[1] the limestones occurring at Balgeddie and Pitkevy, and a third outcrop farther north at Easter Glasslie, are described as detached outliers of the Hurlet Limestone isolated from one another by the injection of the great dolerite sheets of the Lomonds. Absence of intermediate exposures precludes the possibility of asserting whether this is the case or not, but the available evidence does not suggest transgression of the intrusive sheets. The limestone at these three localities (Balgeddie, Pitkevy and Easter Glasslie), previously regarded as the Hurlet seam of the west of Scotland which marks the base of the Lower Limestone Group, is probably the Charlestown Main Limestone which, in the Leslie area, lies some 30-40 fathoms above the base of that group as now defined.[2] No outcrop of any other of the limestones of this group is known in the district so far surveyed around Leslie and Cadham, but their occurrence is proved in a number of bores south of Cadham. The presence of extensive east-west faulting is also disclosed by these bores.

J. E. RICHEY.

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[1] *Op. cit.*, p. 92.

[2] Dinham, C. H., in 'Summary of Progress' for 1923 (*Mem. Geol. Surv.*), 1924, pp. 117-120.

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4. ORKNEY ISLANDS

G. V. Wilson, B.Sc., District Geologist.
J. Knox, B.Sc.
J. V. Stephens, B.Sc., B.Eng. } Geologists.

The survey of Orkney was continued during the past summer by the above named members of the Geological Survey Staff.

Work was restricted to the Mainland and a few adjacent small islands. Mr. Wilson and Mr. Stephens completed the mapping of the West Mainland, except for a small area near Finstown which was done by Mr. Knox, who also finished the survey of the East Mainland.

Middle Old Red Sandstone.—In the West Mainland the mapping of Messrs. Wilson and Stephens has tended to show that the numerous localities in the Stromness Beds from which well preserved fish remains have been obtained lie on the same geological horizon. It has also been noted that the various outcrops are separated by a series of faults with a general northerly trend, and down-throw in most cases to the east. It has not been possible to arrive at any definite conclusions as to the thickness of the Stromness Beds that lie below the fish-bed, but at least 2,000 feet of strata that are thought to be in this position can be seen in an unbroken sequence along the coast of Birsay to the west side of the Broch of Birsay. A tentative base for the Rousay Beds has been taken below a band of grey flags, rich in fragmentary fish and plant remains, which lies about 50 feet below the lowest bed in which *Estheria membranacea* has been found. In the district from Evie to near the Chair of Lyde the position has been fixed fairly accurately, but southwards to Finstown, and eastwards along the southern slopes of Keelylang and Wideford Hills towards Kirkwall the ground is obscure and the line taken is only an approximate one.

Mr. Wilson noted the occurrence of a bed with good fish remains in a quarry at Gallowhall, near Evie. From this locality Mr. Strachan has obtained a number of fairly well preserved fish including *Coccosteus minor*. The bed is sufficiently calcareous to be burnt for lime, and lies about 100 feet above the base of the Rousay Beds. It is probable that this bed occurs at about the same horizon as that in East Hill Quarries, near Kirkwall, from which Hugh Miller[1] obtained numerous specimens of *Coccosteus minor*. If this supposition is correct it implies that a small patch of Stromness Beds lies to the south of Kirkwall. The bed exposed in Pickaquoy quarry to the west of Kirkwall is considered to be the basal *Estheria membranacea* band of the Rousay Beds. It is separated from the

[1] Miller, Hugh, 'Cruise of the Betsy,' 1858, p. 358, and Flett, Sir J. S., 'The Old Red Sandstone of the Orkneys,' *Trans. Roy. Soc. Edin.*, vol. xxxix, pt. ii, 1898, p. 388.

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eastern patch of Stromness Beds by a northerly prolongation of the fault which bounds the eastern coast line of Scapa Flow.

In the West Mainland an occurrence of *Estheria membranacea* has been noted by Mr. Stephens about a mile south of the Stenness Hotel. There is every reason to suppose that a small area of Rousay Beds forms the high ground of Ward Hill. In the Gorseness district of Rendall three beds containing *Estheria* have been noted in about 400 feet of strata. The lowest one is exposed along the coast and is supposed to be that which occurs just above the base of the Rousay Beds.

Owing to the faulted nature of the ground it is difficult to estimate the thickness of the strata that lie between the Stromness Fish Bed and the base of the Rousay Beds. It cannot, however, be much more than 1,000 feet.

Mr. Knox's mapping of the East Mainland shows that the structure of the ground between Deer Sound and Holm Sound is that of a broad anticline trending E.N.E. Rousay Beds occupy most of the ground, but the overlying Eday Sandstone and associated flags occur as a belt on the northern side and extend from Scapa Bay to Yinstay Head. On the south-east the Eday Sandstone is exposed from Dingyshowe to Notster. The structure of the southern part of Deerness is that of a syncline whose axis trends a little west of north. Beds of Rousay age are exposed on both sides and the fish-bed, which is characterised by the presence of *Dipterus valencienisii*, is well seen near Horraquoy on the east coast. A development of contemporaneous volcanic rocks occurs in the group of flags that are characterised by *Tristichopterus alatus*. Except at the Point of Ayre the exposures are poor. The rocks are highly decomposed, and it is very difficult to see what their field relations are. The red marly beds which overlie the *Tristichopterus* flags are seen in the centre of the syncline at Newark Bay.

Igneous Rocks.—Mr. Knox records the occurrence of a small volcanic vent on the shore of the parish of Holm, and about 230 yards south-east of the Tower of Clett. The exposure is only a few yards in extent and occurs in the face of a low cliff. The material of the vent consists of highly decomposed vesicular rock containing numerous rounded and subangular fragments of flagstone, up to 10 inches in diameter. The junction between the igneous material and the flagstones is seen on the north-west side. It is about vertical, and the surrounding sediments dip steeply towards the vent.

The best exposures of the previously mentioned contemporaneous volcanic rocks occur at the Point of Ayre, and probably also in the Black Holm of Copinsay. At the first mentioned locality the material consists of a highly decomposed vesicular basaltic rock. Its relations to the flagstones are rather obscure, but the presence, at the top, of large pipe amygdales, up to a foot in length, an inch in

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diameter and filled in with sandy material tends to prove that the rock is a lava flow. The rock which forms practically the whole of the Black Holm of Copinsay is similar in hand specimen to that of the Point of Ayre. It has a very irregular top and the hollows on its surface are filled in with unaltered shaly and sandy sediments. The exposure is separated by a fault from the Rousay Beds of the Corn Holm and the Ward Holm, but there is no reason to suppose that the rock is of different age to that at the Point of Ayre.

G. V. WILSON.

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III. SECTIONAL REPORTS

I.—PALAEONTOLOGICAL DEPARTMENT

In London

F. L. KITCHIN, Sc.D., PH.D., F.R.S., Palaeontologist (District Geologist).

J. PRINGLE, Assistant-Palaeontologist } (Senior
C. P. CHATWIN, M.Sc., Assistant-Palaeontologist } Geologists).

In Edinburgh

G. W. LEE, D.Sc., Senior Geologist.

A. ENGLAND AND WALES

Two important additions to the series of Palaeontological Memoirs were made by the publication of Professor O. T. Jones's work entitled 'Plectambonites and Some Allied Genera' (vol. i, part 5 of the series), and Miss H. M. Muir-Wood's memoir 'The British Carboniferous Producti. II—*Productus* (*sensu stricto*); *Semireticulatus* and *Longispinus* Groups' (vol. iii, part 1). Professor Jones's monograph treats of certain British brachiopods of late Ordovician and Silurian age, many of which have previously been identified generically with *Plectambonites*, a distinct, early Ordovician generic group. In this work the later forms are fully described and are separated under new generic names. An important feature of the memoir is a comparative table of the British strata from the Llandeilo up to the Ludlow series. Miss Muir-Wood's memoir is a continuation of the work begun by the late Dr. Ivor Thomas on the Carboniferous Productids of this country, the first instalment of which was published in the same series in 1914. The fossils described in both these new memoirs are important in their stratigraphical applications.

During the year an enquiry concerning the occurrence of *Olenellus* in the Lower Cambrian rocks of South Wales again drew attention to a specimen collected by Mr. Pringle in the year 1908 from the red shales at Cwm-bach, near Pen-y-Cwm, Newgale. At the time of collecting the fossil was thought to represent the hypostome of an Olenellid trilobite, but as the locality is situated outside the area comprised in Sheet 227 no mention was made of the specimen in the memoir on that sheet. In view of the interest of the fragment, it has been submitted to Mr. E. S. Cobbold and Dr. F. Raw for a confirming opinion, and both agree that it is undoubtedly the hypostome of *Olenellus* or a closely allied genus. Since this probably constitutes the first known occurrence of an Olenellid in South Wales it seems worthy to be placed on record.

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The results obtained from the examination of a series of specimens stated, in a former publication, to come from the base of the Coal Measures exposed at Oldfields Limeworks, near the Wrekin, were regarded by Mr. Pringle as indicative of a Lower Carboniferous age. A visit to the locality was accordingly arranged, and the additional evidence collected by him and by Mr. S. W. Hester placed beyond question the assignment of these rocks to the Lower Carboniferous.

Amongst the fossils collected by Mr. W. Dewar from the Tarannon Shales of Hughley Brook and other localities in the Shrewsbury district, Mr. Pringle recognized several new species of corals. These are now in the hands of Dr. Stanley Smith for detailed study and description.

Several visits were made to the shaft-sinkings at Cefn-coed, near Neath, and in company with Mr. W. D. Ware, of Ystradgynlais, Mr. Pringle collected a representative suite of fossils from a marine band in the Coal Measures passed through in No. 2 Shaft. This marine bed is the highest of several similar beds lying between the Lower Pinchin and Red Vein coals, and collectively described[1] as the Cwmgorse Marine Beds. The shales have yielded a number of goniatites, several of which Mr. Pringle had previously shown to be identical with forms characteristic of the well-known Mansfield Marine Band.[2]

Certain specimens of *Nautilus nodiferus* Armstrong preserved in the Museum of Practical Geology have been studied by Mr. Pringle and Mr. J. W. Jackson in connexion with their paper showing the value of this shell as a guide-fossil. These authors have established a new genus for this interesting nautiloid, and have figured as *Tylonautilus nodiferus* a specimen from Claughton Brickworks, near Lancaster, exhibited in the Museum.[3] In Scotland *T. nodiferus* characterizes the Arden and Castlecary Limestones, and in the North of England, as far south as Derbyshire, the shell has been found in shales or in limestones referred in some districts to the Yoredale Series and in others to the Millstone Grit. As a result of their researches the authors have shown that this species, when accompanied by goniatites, is proved to be confined to beds just below the Bisulcatum Bed of Zone E of Mr. Bisat's zonal scheme of classification, and is associated with Lower Carboniferous plants. In fact the evidence brought forward in this paper shows that the dividing line between the Lower and Upper Carboniferous, based on

[1] Dix, Miss E., and A. E. Trueman, 'Boreholes in Cwmgorse Valley,' *Proc. South Wales Inst. Engineers*, vol. for 1928, pt. ii, pp. 63-130.

[2] Davies, J. H., and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927 (in Discussion), p. 259.

[3] Pringle, J., and J. W. Jackson, '*Tylonautilus nodiferus* gen. nov.=*Nautilus* (*Discites*) *nodiferus* Armstrong: a Carboniferous Guide Fossil,' *The Naturalist*, 1928, pp. 373-378.

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the flora, agrees with the occurrence of many characteristic Avonian fossils in the uppermost part of the Carboniferous Limestone Series in the North of England and in Scotland, up to the level adopted for the junction between the Lower and Upper Divisions by the late Dr. R. Kidston. *Tylonautilus nodiferus* can be readily recognized, even when fragmentary, by its well-marked sculpture, and by reason of this fact and its narrow vertical range it has proved to be a valuable zonal fossil.

The collections of Cretaceous fossils have recently been enriched by some important additions of well collected material, including many choice specimens. The necessary work of naming, registering, and arranging these sets has been undertaken by Mr. Chatwin. The large series bequeathed by the late Dr. Benjamin Pope Bartlett, the result of more than twenty years of intensive collecting in the neighbourhood of Mere and Maiden Bradley, Wiltshire, gives a very full representation of the fauna of the Cenomanian and Albian beds in that area, and is illustrative of the paper by Dr. Bartlett and Mr. J. Scanes (*Proc. Geol. Assoc.*, vol. xxvii, 1916, pp. 117-134).

The late Gerard Weedon Butler also spent many years collecting, chiefly in the neighbourhood of Reigate, Surrey. His collection, comprising a large series of fossils from the Lower Chalk and also from the Lower Greensand, includes specimens illustrative of his papers ' On a Rich Fauna in the *varians* Zone of the Lower Chalk near Reigate ' (*Geol. Mag.*, 1920, pp. 269-271) and ' On the Perna Bed and the Weald Clay at Reigate ' (*Proc. Geol. Assoc.*, vol. xxxiii, 1922, pp. 313-318). A large proportion of this collection came from the area of Sheet 286, and will therefore form a valuable addition to Survey specimens obtained in that district. Similarly, the Chalk fossils from Western Surrey which formed the basis of Mr. G. W. Young's paper ' On the Chalk Area of Western Surrey ' (*Proc. Geol. Assoc.*, vol. xx, 1908, pp. 422-455) and were presented by him during the year, will serve as a useful supplement to the specimens collected officially from the area of the Aldershot and Guildford Sheet (285).

An extensive set of Cretaceous specimens from the collection made by the late G. W. Lamplugh, also recently dealt with by Mr. Chatwin, includes a fine series of the Lithistid sponges that characterize the Quadratus Zone of the Chalk in Yorkshire. A selected series of specimens from the Upper Chalk of Sussex, presented by Mr. C. T. A. Gaster, is illustrative of his recent work on the subdivisions of the Quadratus Zone on the south coast. Mr. Chatwin has incorporated the more important forms in the exhibited zonal series in the Museum.

The following specimens in the Museum have been figured, described or mentioned in publications :—

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IN THE PALAEONTOGRAPHICAL SOCIETY'S VOLUME FOR THE YEAR 1926
(Published 1928)

A Monograph of the Ammonoidea of the Gault. (Part vi)

By DR. L. F. SPATH, F.G.S.

Callihoplites patella *Spath*, pl. xxi, fig. 4, p. 192.
,, tetragonoides *Spath*, pl. xxi, fig. 3, p. 204.
,, vraconensis (*Pictet and Campiche*), p. 210.
Lepthoplites falcoides *Spath*, text-fig. 75c, p. 235.
,, ornatus *Spath*, text-figs. 78a, b, p. 239.
Schloenbachia subplana (*Mantell*), p. 239.
Pleurohoplites *cf.* renauxianus (*d'Orbigny*), pl. xxiv, fig. 9, p. 243 (3 specimens).
Arrhaphoceras studeri (*Pictet and Campiche*), p. 252.
,, precoupei *Spath*, pl. xxi, figs. 1a, b, pl. xxii, figs. 6a, b, p. 252.
Euhoplites lautus (*J. Sowerby*), *var.* biloba *Spath*, p. 263.

A Monograph of the Fossil Macrurous Crustacea of England. (Part v)

By MR. H. WOODS, M.A., F.R.S., F.G.S.

Mecochirus socialis (*Meyer*), p. 67.

A Monograph of British Dendroid Graptolites. (Part ii)

By DR. O. M. B. BULMAN, D.I.C., A.R.C.S., F.G.S.

Dictyonema irregulare *Hall*, pl. iii, fig. 4, p. 38.
,, sp. *d* ?, text-fig. 35, p. 64.

IN THE PHILOSOPHICAL TRANSACTIONS OF THE ROYAL SOCIETY OF LONDON, SERIES B, VOLUME CCXIV

VI.—*Croonian Lecture.—The Evolution and Origin of the Amphibia*

By PROF. D. M. S. WATSON, F.R.S.

Megalichthys sp., text-fig. 36, p. 250.

IN THE QUARTERLY JOURNAL OF THE GEOLOGICAL SOCIETY, VOLUME LXXXIV

The Lower Carboniferous Rocks of the Menaian Region of Carnarvonshire: their Petrology, Succession and Physiography

By Dr. E. GREENLY, V.P.G.S.

V.—PALAEONTOLOGY

Corals

By DR. STANLEY SMITH, F.G.S.

Dibunophyllum turbinatum (*M'Coy*), p. 404 (9 specimens).
,, sp., p. 404 (4 specimens).
Clisiophyllum sp., p. 404 (2 specimens).

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Koninckophyllum magnificum *Thomson & Nicholson*, p. 404 (2 specimens).
,, sp., p. 404.
Caninia juddi (*Thomson*), p. 405.
,, sp. nov. i, p. 405 (2 specimens).
,, sp. nov. ii, p. 405 (3 specimens).
Lonsdaleia duplicata (*Martin*), p. 405 (12 specimens).
,, floriformis (*Martin*), p. 405 (12 specimens).
Corwenia rugosa (*M'Coy*), p. 406 (8 specimens).
Lithostrotion irregulare (*Phillips*), p. 406 (25 specimens).
,, junceum (*Fleming*), p. 406 (6 specimens).
,, portlocki (*Bronn*), p. 406 (17 specimens).
,, maccoyanum *Edwards & Haime*, p. 406 (2 specimens).
,, martini *Edwards & Haime*, p. 406 (4 specimens).
Diphyphyllum *aff.* lateseptatum *M'Coy*, p. 406 (23 specimens).
Syringopora reticulata *Goldfuss*, p. 407 (11 specimens).
,, *cf.* ramulosa *Goldfuss*, p. 407 (9 specimens).
,, catenata (*Martin*), p. 407 (2 specimens).

Brachiopods

By Miss H. M. Muir-Wood, M.Sc., F.G.S.

Productus giganteus (*Martin*), p. 407 (6 specimens).
,, sp. nov. i, [*aff.* giganteus (*Martin*)], p. 407 (5 specimens).
,, sp. nov. ii, [*aff.* giganteus (*Martin*)], p. 407 (5 specimens).
,, striatus *Fischer de Waldheim*, p. 407 (5 specimens).
,, *aff.* auritus *Phillips*, p. 407 (3 specimens).
,, hemisphericus *J. Sowerby*, p. 407 (8 specimens).
,, latissimus *J. Sowerby*, p. 408 (21 specimens).
,, sp. nov. iii, [*aff.* latissimus *J. Sowerby*], p. 408 (8 specimens).
,, sulcatus ? *J. de C. Sowerby*, p. 408.
,, redesdalensis ? *Muir-Wood*, p. 408 (2 specimens).
Pustula elegans (*M'Coy*), p. 408.

The Flora

By Mr. John Walton, M.A., F.G.S.

Rhodea sp., text-fig. 4, p. 409.
Cf. Stigmaria (*rootlets*), p. 410.
Knorria sp. (? Lepidodendron), p. 410.
? Telangium (*rachises*), p. 410.

In the Annals and Magazine of Natural History, Volume I, Tenth Series

Spirifer pennystonensis *sp. n., from the Coal Measures of Coalbrookdale.*

By Mr. T. Neville George, M.Sc.

Spirifer pennystonensis *George*, pl. iv, figs. 1a, b, p. 109.

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IN THE MEMOIRS AND PROCEEDINGS OF THE MANCHESTER LITERARY AND PHILOSOPHICAL SOCIETY, VOLUME LXXII

XIII.—*On* Beyrichia kloedeni *M'Coy*

By MR. S. H. STRAW, M.Sc., F.G.S.

Beyrichia kloedeni *M'Coy*, pl. i, figs. 7, 8, p. 197.

IN TYPE AMMONITES, VOLUME VII

By MR. S. S. BUCKMAN, F.G.S.

Anguidactylites anguiformis *S. Buckman*, pl. dcclxii, figs. 1-3.
Harpoceras falciferum (*J. Sowerby*), pl. dcclxiv A, figs. 1, 2.
Phaularpites exiguus *S. Buckman*, pl. dcclxxv B, figs. 1, 2, p. 13.
Toxodactylites toxophorus *S. Buckman*, pl. dcclxxvi, figs. 1, 2.
Spinicoeloceras spicatum *S. Buckman*, pl. dcclxxvii, figs. 1, 1a, 2.
Peridactylites consimilis *S. Buckman*, pl. dcclxxviii, figs. 1, 2.
Parvidactylites parvus *S. Buckman*, pl. dcclxxix (2 views).
Multicoeloceras multum *S. Buckman*, pl. dcclxxxv, figs. 1, 1a, 2.

IN THE NATURALIST

The Genus Fayolia

By DR. R. CROOKALL, F.L.S.

Fayolia crenulata *Moysey*, pl. viii, figs. 2, 3, p. 332 (6 specimens).
,, moyseyi *Pruvost*, pl. viii, fig. 4, p. 361 (2 specimens).

Tylonautilus nodiferus *gen. nov.*=Nautilus (Discites) nodiferus *Armstrong*: *A Carboniferous Guide Fossil*

By MR. J. PRINGLE, F.G.S. and MR. J. WILFRID JACKSON, M.Sc., F.G.S.

Tylonautilus nodiferus (*Armstrong*), pl. xi (2 views), p. 373.

IN BRITISH MUSEUM (NATURAL HISTORY)—CATALOGUE OF FOSSIL CIRRIPEDIA, VOLUME I

Triassic and Jurassic

By MR. T. H. WITHERS, F.G.S.

Eolepas aalensis (*Richardson*), pl. i, figs. 12, 13, p. 70 (5 specimens).
,, oolitica (*J. Buckman*), p. 73 (4 specimens).
Zeugmatolepas concinna (*Morris*), pl. vii, fig. 2; pl. ix, fig. 3, p. 99.

IN MEMOIRS OF THE GEOLOGICAL SURVEY. SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY OF GREAT BRITAIN AND THE MUSEUM OF PRACTICAL GEOLOGY FOR THE YEAR 1927, Part ii

XIII.—*Palaeozoic species of* Vetacapsula *and* Palaeoxyris

By DR. R. CROOKALL, F.L.S.

Vetacapsula cooperi *Mackie*, pl. i, fig. 4, p. 91 (2 specimens).
,, moyseyi *Crookall*, pl. i, fig. 6, p. 92.
Palaeoxyris pringlei *Crookall*, pl. ii, fig. 2, p. 103.
,, helicteroides (*Morris*), p. 98 (2 specimens).
,, carbonaria *Schimper*, p. 99 (2 specimens).
,, sp., p. 89.

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In Memoirs of the Geological Survey of Great Britain; Palaeontology—Volume I. (Part 5)

Plectambonites and Some Allied Genera

By Professor O. T. Jones, M.A., D.Sc., F.R.S.

Chonetes minima (*J. de C. Sowerby*), p. 389.
" Strophomena " fletcheri (*Davidson*), p. 389.
Sowerbyella sericea (*J. de C. Sowerby*), pl. xxi, figs. 1-4, p. 414 (8 specimens).
,, ,, *var.* soudleyensis *Jones*, pl. xxi, figs. 5, 6, p. 417 (3 specimens).
,, antiqua *Jones*, pl. xxi, figs. 7-11, p. 419 (5 specimens).
,, sladensis *Jones*, pl. xxi, figs. 14-17, p. 421 (8 specimens).
,, ,, *var.* simulans *Jones*, pl. xxi, figs. 18-20, p. 423.
,, thraivensis (*Reed*), pl. xxi, figs. 21-23, p. 425.
,, *cf.* rhombica (*M'Coy*), pl. xxii, fig. 2, p. 429 (4 specimens).
,, rhombica, *var.* conspicua (*Reed*), pl. xxii, figs. 3-5, p. 430 (7 specimens).
,, duplicata (*J. de C. Sowerby*), pl. xxii, figs. 6-13; pl. xxiii, figs. 1, 2, p. 432 (10 specimens).
,, precursor *Jones*, pl. xxiii, figs. 3-5, p. 437 (3 specimens).
,, *cf.* precursor *Jones*, p. 404.
,, mullochensis (*Reed*), pl. xxiii, figs. 6-8, p. 439 (6 specimens).
,, mullochensis (*Reed*), *var.*? pl. xxiii, fig. 9, p. 441 (3 specimens).
,, superstes *Jones*, pl. xxiii, figs. 10-12, p. 441.
,, penkillensis (*Reed*), p. 443 (3 specimens).
,, millinensis *Jones*, pl. xxiii, figs. 13-16, p. 444 (4 specimens).
,, ,, *var.* canastonensis *Jones*, pl. xxiii, figs. 17, 21, 22, p. 447.
,, ,, *var.* parabola *Jones*, pl. xxiii, figs. 18-20, p. 446 (6 specimens).
,, transversalis (*Davidson*), pars [*Wahlenberg*?], pl. xxiii, fig. 23; pl. xxiv, fig. 1, p. 448 (8 specimens).
,, ,, *var.* lata *Jones*, pl. xxiv, fig. 2, p. 450 (8 specimens).
,, duvali (*Davidson*), p. 452 (26 specimens).
,, undulata (*Salter*), pl. xxiv, figs. 4-6, p. 452 (6 specimens).
,, ,, *var.* maccoyi *Jones*, p. 458.
,, ,, *var.* tricostata (*Reed*), pl. xxiv, figs. 8, 9, p. 458 (5 specimens).
,, plicata *Jones*, pl. xxiv, figs. 10, 11, p. 459 (5 specimens).
,, compressa *Jones*, pl. xxiv, figs. 12, 13, p. 460 (3 specimens).
,, subcorrugatella (*Reed*), pl. xxiv, figs. 14, 15, p. 463.
,, quinquecostata (*M'Coy*), emend *Jones*, pl. xxiv, figs. 16-20, p. 464 (12 specimens).
,, gracilis *Jones*, pl. xxiv, figs. 21-25, p. 472 (6 specimens).
Sowerbyella ? youngiana (*Davidson*), p. 495.
Leptelloidea leptelloides (*Bekker*), pl. xxiv, fig. 26; pl. xxv, figs. 1, 2, p. 475.
,, llandeiloensis (*Davidson*), p. 478.
,, scissa (*Davidson*), pars, pl. xxv, figs. 8-11, p. 481 (8 specimens).
,, segmentum (*Lindström*), pl. xxv, figs. 13-18, p. 485 (6 specimens).
,, sholeshookensis *Jones*, pl. xxv, fig. 19, p. 488 (4 specimens).
,, ruralis (*Reed*), pp. 491, 492 (10 specimens).

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Chonetoidea garthensis *Jones*, pl. xxv, figs. 25, 26, p. 500.
Chonetoidea ? sp. 1, p. 501 (2 specimens).
Chonetoidea sp. 3, p. 502 (2 specimens).

In Memoirs of the Geological Survey of Great Britain; Palaeontology—Volume III. (Part 1)

The British Carboniferous Producti

II.—Productus (sensu stricto); Semireticulatus *and* Longispinus *Groups*

By Miss H. M. Muir-Wood, M.Sc.

Productus productus (*Martin*), pl. i, figs. 1 (4 views), 5, 6, p. 39 (19 specimens).
,, ,, *var.* hispidus *Muir-Wood*, p. 48 (5 specimens).
,, insculptus *Muir-Wood*, pl. iii, fig. 10 (2 views), p. 89.
,, pinguis *Muir-Wood*, pl. v, fig. 1, p. 104 (2 specimens).
,, multispiniferus *Muir-Wood*, pl. viii, fig. 2, p. 121 (4 specimens).
,, pugilis *Phillips*, pl. ix, fig. 1 (2 views), p. 133 (16 specimens).
,, sulcatus *J. Sowerby*, pl. x, figs. 4, 5 (2 views), p. 147 (22 specimens).
,, triquetrus *Muir-Wood*, pl. xi, fig. 7 (3 views); pl. xii, fig. 18 (3 views), p. 163 (7 specimens).
,, concinnus *J. Sowerby*, pp. 52, 53 (19 specimens).
,, carbonarius *de Koninck*, pp. 58, 59 (8 specimens).
,, redesdalensis *Muir-Wood*, p. 63 (3 specimens).
,, vaughani *Muir-Wood*, pp. 68, 69 (2 specimens).
,, griffithianus *de Koninck*, p. 75 (2 specimens).
,, muricatus *Phillips*, p. 81 (3 specimens).
,, furcatus *Muir-Wood*, p. 87.
,, semireticulatus (*Martin*), p. 96 (6 specimens).
,, projectus *Muir-Wood*, pp. 102, 103 (2 specimens).
,, hindi *Muir-Wood*, p. 111 (4 specimens).
,, antiquatus *J. Sowerby*, p. 117.
,, longispinus *J. Sowerby*, p. 159 (4 specimens).
,, tissingtonensis *Sibly*, p. 169 (18 specimens).
,, derbiensis *Muir-Wood*, pp. 172, 173 (3 specimens).
,, lobatus *J. Sowerby*, p. 176 (4 specimens).
,, ,, *var.* laqueatus *Muir-Wood*, p. 179.
,, setosus *Phillips*, pp. 186, 187 (34 specimens).
,, minutus *Muir-Wood*, p. 196 (4 specimens).
Buxtonia sp., pl. xii, fig. 20, p. 36.

In Stratigraphical Palaeontology, A Manual for Students and Field Geologists

By Dr. E. Neaverson, F.G.S.

Orthis calligramma *Dalman*
,, lunata *J. de C. Sowerby*
Bilobites biloba (*Linné*)
Nicolella actoniae (*J. de C. Sowerby*)
Dinorthis flabellulum (*J. de C. Sowerby*)
Heterorthis alternata (*J. de C. Sowerby*)
Harknessella vespertilio (*J. de C. Sowerby*)
Hebertella crispa (*M'Coy*)
Dalmanella elegantula (*Dalman*)
} text-fig. 27, p. 212.

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Conchidium knighti (*J. Sowerby*)
Barrandella globosa (*J. de C. Sowerby*)
,, undata (*J. de C. Sowerby*) } text-fig. 29, p. 231.
Pentamerus oblongus (*J. de C. Sowerby*)
Stricklandinia lens (*J. de C. Sowerby*)
Leptaena rhomboidalis (*Wilckens*)
Christiania tenuicincta (*M'Coy*)
Triplecia (Cliftonia) spiriferoides (*M'Coy*) } text-fig. 30, p. 234.
Strophomena expansa (*J. de C. Sowerby*)
Plectambonites sericea (*J. de C. Sowerby*)
Staurocephalus globiceps (*Portlock*), text-fig. 31, p. 237.
Pugnax acuminatus (*Martin*) } text-fig. 33, p. 257.
Camarotoechia borealis (*Schlotheim*)
Athyris expansa (*Phillips*)
Composita ambigua (*J. Sowerby*)
Spirifer pinguis *J. Sowerby* } text-fig. 34, p. 260.
Cyrtia exporrecta *Wahlenberg*
Meristina tumida (*Dalman*)
Productus latissimus *J. Sowerby*, text-fig. 35, p. 268.
Anisoloboceras nautiliforme (*J. Buckman*), text-fig. 42, p. 335.
Strigoceras truelli (*d'Orbigny*)
Chondroceras delphinus *S. Buckman* } text-fig. 46, p. 352.
Teloceras labrum *S. Buckman*
Cosmoceras acutistriatum *Robson*, text-fig. 49, p. 363.
Trigonia caudata *Agassiz*
,, clavellata *J. Sowerby*
,, costata *J. Sowerby*
,, duplicata *J. Sowerby* } text-fig. 52, p. 369.
,, gibbosa *J. Sowerby*
,, nodosa *J. de C. Sowerby*
,, v-costata *Lycett*
Ringsteadia pseudocordatus (*Blake & Hudleston*)
Prionodoceras superstes (*Phillips*) } text-fig. 54, p. 375.
Cardioceras quadrarium *S. Buckman*
Turrilites wiesti *Sharpe*, text-fig. 59, p. 406.
Neithea quinquecostatus (*J. Sowerby*), text-fig. 62, p. 417.

B. Scotland

The Old Red Sandstone of the Orkney Islands has yielded a fine suite of fossil fishes and plants. The fishes have been submitted to Professor D. M. S. Watson, F.R.S., and the plants to Professor W. H. Lang, F.R.S., and results of importance are likely to be obtained from the study of these materials. Professor Watson has furnished the following preliminary note on the fish remains :—

' Large collections of Old Red Sandstone fishes have been made from the West Mainland, from Deerness, South Ronaldshay, Sanday, and Eday. The collections from the Rousay and Eday Beds consist largely of the remains of Dipnoan fish, a condition in striking contrast to that which exists in the Stromness Beds and their equivalents in the Moray Firth region.

' The extensive collections made during the last two seasons in Orkney confirm the late Dr. Traquair's faunal separation of the Stromness, Rousay and Eday Beds, whilst adding some new forms.

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There is now evidence of the association of a small square-scaled Osteolepid with *Tristichopterus* in the Eday Beds of South Ronaldshay, unfortunately represented by undeterminable fragments.

'The large Coccostean to which I referred in last year's *Summary of Progress* has now been found 875 yards W.41°N. of Warsetter Farm, Sanday, in association with *Tristichopterus* and *Pentlandia* in the Eday Beds. It is also known from Inganess Farm, Kirkwall, in Rousay Beds (?), and from Newark Bay, Deerness, in what are assumed to be Eday Beds. It is thus probable that it is restricted to a narrow belt of rocks.

'A small *Dipterus*, which is exceedingly abundant on the shore 460 yards east of Horraquoy, Deerness, cannot be definitely distinguished from *Dipterus valenciennesi*, but it is usually much smaller, and has so characteristic an appearance that it may in the future be possible to differentiate it. It presumably belongs to a horizon near the summit of the Rousay Beds.'

While no specimens of outstanding interest have been obtained during visits to the numerous borings in Carboniferous rocks, the fossils have proved to be of the utmost value in establishing the sequence of the rocks passed through, and in some instances they have helped to elucidate the stratigraphical relations of certain limestones in districts where good natural exposures are not available.

The discovery of '*Edmondia*' *punctatella* (Jones) in the Douglas Coalfield is worthy of special note. Specimens of this interesting shell were found in the bed of Kennox Water at a point 700 yards E.23°S. of Chapel Hill. This species is an index to the position of the Calmy Limestone, and as the shell has been traced over a great part of Central Scotland, it has a stratigraphical value of considerable importance. '*E.*' *punctatella* is itself of some biological interest. The shell was formerly regarded as belonging to the Eucrustacea, but was afterwards placed among the Mollusca by T. R. Jones. Later, W. Hind described it under the name *Edmondia punctatella*; but a close study of the specimens tends to confirm the opinion of the late Dr. G. W. Lee that a new generic name is required. It may be pointed out that *Edmondia* is a definitely marine shell, whereas '*E.*' *punctatella* is estuarine.

F. L. KITCHIN.

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2.—PALAEOBOTANICAL WORK

The chief item of work during the year has consisted in the examination and identification of fossil plants sent in from the following one-inch sheets: 8, 15, 23, 32, 75, 85, 109, 110, 152, 230, 231 (England), and 14, 22, 30, 31, 39 (Scotland), while fossils from the Bristol and Derbyshire Coalfields have been identified for outside workers.

Dr. Crookall has prepared a catalogue of the 4,000 photographic negatives in the Kidston Bequest, with details as to the collection and number of the fossil, size of plate, multiplication, details shown, if and where figured, etc. Most of the photographs are of impressions in the Kidston Collection, but there are also numerous negatives of fossils in most of the British museums, as well as of specimens in private collections. Negatives of micro-sections in the Scott and other collections are also present.

With considerable assistance on the stratigraphical side from Mr. E. B. Bailey, an account of the flora of the Coal Measures of Ayrshire has been written, this being incorporated in the North Ayrshire Memoir, now in the press. Dr. Crookall has also revised the palaeobotanical section for the Huddersfield Memoir, prepared by Mr. C. E. N. Bromehead.

General assistance has been given in checking the lists of plants appearing in the various Sheet memoirs issued during the year, and those at present passing through the press, while many enquiries have been answered and assistance given to research workers and others.

An account of the stratigraphical distribution of the 584 known species of British Coal Measures plants has been drawn up, and their application as zonal indices reviewed, while similar treatments of the Lower Carboniferous flora and of the British Carboniferous petrifactions are in course of preparation.

In continuance of critical studies of *Vetacapsula*, *Palaeoxyris* and *Fayolia* a new species of the last named genus has been described, and the genus reviewed.

The following specimens in the Kidston and palaeobotanical collections have been figured, described or mentioned in publications:—

IN THE SUMMARY OF PROGRESS OF THE GEOLOGICAL SURVEY FOR 1927, PART II

(published 1928)

XIII.—*Palaeozoic species of* Vetacapsula *and* Palaeoxyris

By R. CROOKALL, PH.D.

Vetacapsula johnsoni (*Kidston*), pl. i, fig. 5, p. 93 (No. K. 908).
,, kidstoni *Crookall*, pl. i, figs. 7, 8, p. 95 (Nos. R.C. 245, 248).
Palaeoxyris edwardsi *Crookall*, pl. ii, fig. 3, p. 103 (No. R.C. 255).
,, warei *Crookall*, pl. ii, fig. 6, p. 102 (No. R.C. 256).

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? Palaeoxyris sp., pl. ii, fig. 5, p. 104 (No. R.C. 252).
Specimens mentioned, viz. :—
Vetacapsula moyseyi *Crookall*, p. 93 (No. K. 6994).
,, johnsoni (*Kidston*), p. 94 (No. K. 191).
,, kidstoni *Crookall*, p. 95 (Nos. R.C. 246, 247).
Palaeoxyris helicteroides (*Morris*), p. 99 (Nos. K. 593, 4153, 6976-6981).
,, carbonaria *Schimper*, p. 100 (Nos. K. 6973-6975).
,, prendeli *Lesqx.*, p. 101 (Nos. 190, 192, 4151).

IN 'THE NATURALIST' FOR NOVEMBER AND DECEMBER, 1928, p. 325

The Genus Fayolia

By R. CROOKALL, Ph.D.

Fayolia warei *Crookall*, pl. viii, fig. 1, p. 362 (No. R.C. 253).
Specimens mentioned, viz. :—
Fayolia crenulata *Moysey*, p. 332 (Nos. K. 4149, 4150).

IN STRATIGRAPHICAL PALAEONTOLOGY, A MANUAL FOR STUDENTS AND FIELD GEOLOGISTS, 1928

By E. NEAVERSON, D.Sc.

Sphenophyllum emarginatum *Brongt.*, text-fig. 40, p. 298 (No. K. 2302).
Neuropteris macrophylla *Brongt.*, text-fig. 40, p. 298 (No. K. 290).
Dactylotheca plumosa (*Artis*), text-fig. 40, p. 298 (Nos. K. 2107, 2111).
Renaultia gracilis (*Brongt.*), text-fig. 40, p. 298 (No. K. 775).
Zeilleria delicatula (*Sternb.*), text-fig. 40, p. 298 (No. K. 204).
Telangium affinis (*L. & H.*), text-fig. 40, p. 298 (No. K. 644).

R. CROOKALL.

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3.—PETROGRAPHICAL WORK

Petrographical work has been, apart from routine duties in the Department, mainly in connexion with the forthcoming memoirs on Ardnamurchan and Coll in Scotland and the Cheviot region in England. Work has also been carried out in relation to other districts in progress of surveying.

The petrology of the Tertiary rocks of Ardnamurchan has been entirely in the hands of the Petrographer, but Mr. Bailey has undertaken the descriptive petrology of the older rocks of Coll and the mainland. Frequent references have been made to the petrology of Ardnamurchan in the *Summaries of Progress* for past years and the publication of full details in the immediate future renders unnecessary any further discussion of the subject in this place. It may be said, however, that Ardnamurchan exemplifies in simple yet striking manner the phenomena of ring-dyke intrusion, and presents many new facts that are of considerable importance in relation to magmatic differentiation and petrogenesis. The range of rock-types is fairly large, and fresh light is thrown upon the form and mechanics of their intrusion. The idea of magma-types enunciated for Mull has been developed, while an endeavour has been made to trace their genetic connexions and account for their differences. Hybridization is considered to play some part in the genesis of certain rock types and structures, and is held to be responsible for the tonalitic and monzonitic types that occupy the centre of the latest complex. The fact that Ardnamurchan is the last remaining important area of Tertiary igneous rocks to be dealt with has impressed the authors of the memoirs with the desirability of reviewing, if space permits, the subject of Tertiary igneous activity in Britain in the light of the most recent work.

In other fields Mr. A. G. MacGregor has completed a detailed study of the lavas of Carboniferous and Old Red Sandstone age in Ayrshire, the results of which will be found embodied in the memoir on North Ayrshire, now in the press.

Dr. H. H. Read has engaged in a comparative study of the Lewisian rocks of the north-west of Scotland and has made full use of the mass of material collected by the earlier surveyors, and preserved in our collections.

HERBERT H. THOMAS.

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4.—CHEMICAL WORK

During 1928 the quantitative analyses completed were mainly for the Scottish Memoirs and include the following :—

858. *Epidiorite.* Boss in Moine Series. 160 yds. W. of Loch a'Mhoid. 6-inch map, Sutherland, 43 S.E. Slice No. S. 25690.

859. *Serpentine.* Mass in Moine Series. Allt Diona-Choire, 1 mile W. of north end of Loch na Bruthaiste. 6-inch map, Sutherland, 43 N.E. Slice No. S. 25691.

860. *Pulaskite.* Part of Loyal 'Granite.' S.W. slope of Cnoc Arach nan Cuilean, 1⅛ miles N.10°W. of Innisceananlocha. 6-inch map, Sutherland, 35 S.W. Slice No. S. 25692.

861. *Scyelite* (altered). Boss in Moine Series. Shore of Loch Shin, at foot of path from Overscaig Inn. 6-inch map, Sutherland, 73 N.W. Slice No. S. 25693.

878. *Cordierite-diaspore-hornfels.* Contact-altered Greenstone. Inner Quarry, Kenidjack, near St. Just. 6-inch map, Cornwall, 67 S.W. Slice No. E. 14058.

879. *Bostonite.* Dyke. The Haven, Swona, Orkney. 1-inch map, Scot., 117. Slice No. S. 25818.

Lab. Nos.	858	859	860	861	878	879
SiO_2 ...	50·02	37·53	63·33	43·56	33·58	60·69
Al_2O_3 ...	15·36	0·72	16·98	3·06	11·79	20·91
Fe_2O_3 ...	2·29	5·12	1·41	3·59	11·27	1·61
FeO ...	8·08	1·78	1·14	3·80	17·50	0·09
MgO ...	7·76	37·99	1·17	31·32	15·55	0·09
CaO ...	8·81	1·32	2·58	3·57	0·89	0·12
Na_2O ...	2·94	0·18	6·06	0·29	0·60	1·66
K_2O ...	1·30	0·03	5·90	1·31	0·32	11·34
$H_2O > 105°C.$	1·01	11·75	0·18	7·04	4·60	2·67
$H_2O < 105°C.$	0·16	0·68	0·14	0·14	0·13	0·52
TiO_2 ...	1·80	0·09	0·53	0·37	2·96	0·16
P_2O_5 ...	0·14	0·00?	0·24	0·02	0·36	0·07
MnO ...	0·18	0·17	0·10	0·19	0·21	0·02
CO_2 ...	0·12	2·04	0·00?	1·31	0·00	0·00
Cl	—	—	—	—	0·02	0·00
F	0·00?	0·00	0·00?	0·00	0·00	0·00
FeS_2 ...	0·19	0·29	0·14	0·32	—	—
Fe_7S_8 ...	0·00?	0·00?	0·00	0·00	—	—
Cr_2O_3 ...	0·00?	0·33	0·00?	0·25	0·00	0·00
NiO, CoO ...	0·00	0·08	0·00	0·02	0·00	0·00
BaO ...	0·00	0·00	0·34	0·00	—	—
Li_2O ...	0·00	0·00	0·00?	0·00	0·00	0·00?
Totals ...	100·16	100·10	100·24	100·16	99·78	99·95
Analysed by	B. E. Dixon				R. Sutcliffe	

868. *Teschenite* with some biotite; olivine completely serpentinised; felsic minerals somewhat altered, as is usual in teschenites. Sill cutting underlying quartz-dolerite of Craigens Sill Complex. Probably Permian. Railway cutting, 100 yards W.N.W. of Sykeside, barely 1½ miles E.S.E. of Town Hall, Cumnock. 6-inch map, Ayr, 35 S.E. Slice Nos. S. 25771 and S. 25529.

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869. *Olivine-free Camptonitic Hornblende-teschenite*, allied to lugarite; felsic minerals much altered. Sill, probably Permian. Glaisnock Hill, 1,000 yards S.15°W. of Over Glaisnock, 2 miles S.18°E. of Cumnock. 6-inch map, Ayr, 41 N.E. Slice Nos. S. 25772 and S. 25512.

870. *Picrite*. (Abundant olivine, mostly fresh; some biotite; sparse felsic minerals much altered.) Ultra-basic facies of theralitic essexite of Kyle type. Picrite facies of kylite sill, probably Permian. Craigdonkey, Beuquhat Hill, 900 yards N.N.E. of school, Beuquhat. 6-inch map, Ayr, 46 N.E. Slice Nos. S. 25773 and S. 25515.

871. *Non-ophitic Essexitic Olivine-dolerite*. (Fresh rock.) Closely allied to the less mafic theralitic essexites of Kyle type. Outer part of composite intrusion, cutting Cementstone Series. Probably Permian. Elongated hill, 550 yards W.40°S. of Carskeoch, 1 mile S. of Patna. 6-inch map, Ayr, 46 N.W. Slice Nos. S. 25774 and S. 25518.

872. *Monchiquitic Olivine-basalt*. (Fresh rock but analcite cloudy.) Dyke cutting ash neck (probably Permian in age), which cuts Carboniferous Limestone Series. Patna Hill, 1,130 yards W.9°S. of Downieston, Patna. 6-inch map, Ayr, 46 N.W. Slice Nos. S. 25775 and S. 25521.

873. *Theralitic Essexite* of Crawfordjohn Type. (Fresh except for alteration of felspathoid minerals.) Intrusion in ash neck (probably Permian in age), which cuts strata near base of Cementstone Series. Carclout Hill, quarry beside wall, 1¼ miles W.S.W. of Patna. 6-inch map, Ayr, 45 N.E. Slice Nos. S. 25776 and S. 25522.

Lab. Nos.	868	869	870	871	872	873
SiO_2 ...	47·97	45·13	43·15	48·30	45·13	46·64
Al_2O_3 ...	14·87	14·78	8·67	16·34	13·07	17·68
Fe_2O_3 ...	2·81	4·61	2·86	0·82	2·55	1·79
FeO ...	6·93	5·74	9·83	9·31	7·97	8·17
MgO ...	5·55	5·69	20·70	6·74	12·65	5·98
CaO ...	8·27	10·59	7·16	10·59	10·18	11·69
Na_2O ...	3·81	3·76	1·66	2·91	2·32	3·06
K_2O ...	2·31	2·37	0·73	1·13	1·12	1·34
$H_2O > 105°C.$	4·26	3·41	3·86	1·02	2·44	1·44
$H_2O < 105°C.$	0·67	0·37	0·26	0·10	0·17	0·06
TiO_2 ...	2·09	2·72	0·92	2·07	1·57	1·61
P_2O_5 ...	0·27	0·55	0·29	0·34	0·49	0·42
MnO ...	0·43	0·26	0·33	0·29	0·38	0·39
CO_2 ...	0·05	0·32	0·16	0·07	0·02	0·00
Cl	0·00	0·01	0·01	0·00	0·00	0·01
F	0·00	0·03	0·00	0·02	0·03	0·00
FeS_2 ...	0·00	0·00	0·00	0·00	0·00	0·03
NiO, CoO ...	0·00	0·03	0·03	0·02	0·03	0·02
BaO ...	0·00	0·01	0·00	0·00	0·02	0·01
Li_2O ...	0·00?	0·00?	0·00	0·00	0·00	0·00
Less O for F	—	0·01	—	—	0·01	—
Totals ...	100·29	100·37	100·62	100·07	100·13	100·34
Analysed by	E. G. Radley.					

B. E. Dixon.

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IV. MUSEUM OF PRACTICAL GEOLOGY

Museum work continues to be hampered by the state of the building, and pending the removal to South Kensington improvements and rearrangements of the displayed material cannot be undertaken. The total number of visitors during the year was 20,287, of which 1,409 were Sunday visitors. Twenty-six demonstrations were given to schools and institutions, the aggregate attendance being 434.

Special exhibits were prepared for the conference of Empire Surveyors who visited the museum in July, for the Geologists' Association, for the Yorkshire Geological Society Exhibition at Leeds and for the Technical Institute at Folkestone. Certain cases have been cleaned and rearranged and special exhibits illustrating, amongst other things, the Wabana Iron Ore, the occurrence and association of Burmese Jadeite, and Geological Survey Maps published in 1928, are now displayed.

Registration of material and cataloguing of the collections has been carried on steadily; 1,588 specimens of the Lindsey Collection and 308 specimens of the Ludlam Collection were numbered, registered and card-indexed; a card index of Scottish geological photographs was begun and 950 cards completed by the end of the year. The revision of the Catalogue of Instruments was undertaken. A new catalogue was prepared, checked and substantial progress made with arrears of engraving.

In the absence in the field of the photographer, the museum staff supplied to the order of the public 154 lantern slides and 106 prints of Geological Survey photographs. A certain amount of field collecting and photography was also completed, and 60 rock sections were prepared.

For a considerable part of the year the Curator was engaged in geophysical work in the field with the Eötvös Torsion Balance. The results of one of the surveys are now in the press, whilst the necessary field work for another survey has been completed. In the course of this work training in the method was given to officers of the Australian and Canadian Governments.

The additions to the library during the past year comprise 261 volumes of independent works, 3,233 volumes and parts of serials, 207 pamphlets, 475 maps and 262 geological photographs. The Survey Collection of photographs now numbers 8,500, and there has been a growing demand for prints and lantern slides, work which is now executed by the Survey and Museum staffs; 471 lantern slides and prints were supplied to the public. The library continues to be used by students, mining engineers and professional enquirers to an increasing degree.

W. F. P. McLintock.

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I.—A GRAVITATIONAL SURVEY OVER THE BURIED KELVIN VALLEY AT DRUMRY, NEAR GLASGOW

BY

W. F. P. McLintock, D.Sc., and James Phemister, M.A., D.Sc.

Text-figures 1 to 5.

INTRODUCTION

In this country where so much of the solid geology is obscured by glacial deposits of variable thickness a knowledge of subdrift topography, apart from its scientific interest to glacial geologists, is often of considerable economic importance especially in coalfield areas where the presence of buried channels filled with clay or sand may seriously complicate mining operations. Owing to the fact that the drift is of moderate thickness and usually has a lower specific gravity than the subjacent rock, pronounced irregularities in the rock-surface frequently cause distinct gravitational anomalies readily detectable by the Eötvös Torsion Balance. In fact, in the investigation of geological structure by a torsion balance survey, it may happen that these irregularities produce local gravitational effects sufficiently large to obscure the effects due to the structure, and the disentangling of such local anomalies is a necessary preliminary to a successful geological interpretation of the balance results. It follows that gravitational survey with the torsion balance is an obvious method of mapping subdrift topography and it was decided to put it to a practical test in an area where subdrift irregularities were known from boring and mining evidence and where the surface topography was sufficiently irregular to demand careful evaluation of terrain and topographic corrections.

The buried channel of the River Kelvin, about 7 miles west-north-west of Glasgow, was selected as a test area fulfilling the necessary requirements. The existence of this channel has long been known from an extensive series of borings put down in search of coal and ironstone. The borings proved the presence not only of a deep, drift-filled channel but also of a mass of rock rising abruptly through the drift to 74 ft. from the surface near Drumry. The district is one of moderate relief (see map, Fig. 2), and it was therefore considered that, whilst the corrections for terrain and topography would be large and demand careful evaluation, there would still remain residual gravitational effects sufficiently large to enable the evidence of the subdrift features gained from the borings to be confirmed and, perhaps, extended.

Operations were commenced in November 1927, and continued until March 1928, during which period 68 stations were determined by visual observation at night. A complete account of the work with the relevant mathematical analysis has already appeared[1]

[1] *Trans. Roy. Soc. Edin.*, vol. lvi, part 1 (No. 7), 1929, pp. 141-155.

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but a short resumé of the results is given here in the hope that it may interest geologists in a new method of investigating a difficult and important problem.

THE NATURE OF THE TEST

The map, Fig. 1, reproduced from the Geological Survey Memoir on the Geology of the Glasgow District, shows the contours of the buried rock surface after removal of the superficial deposits in

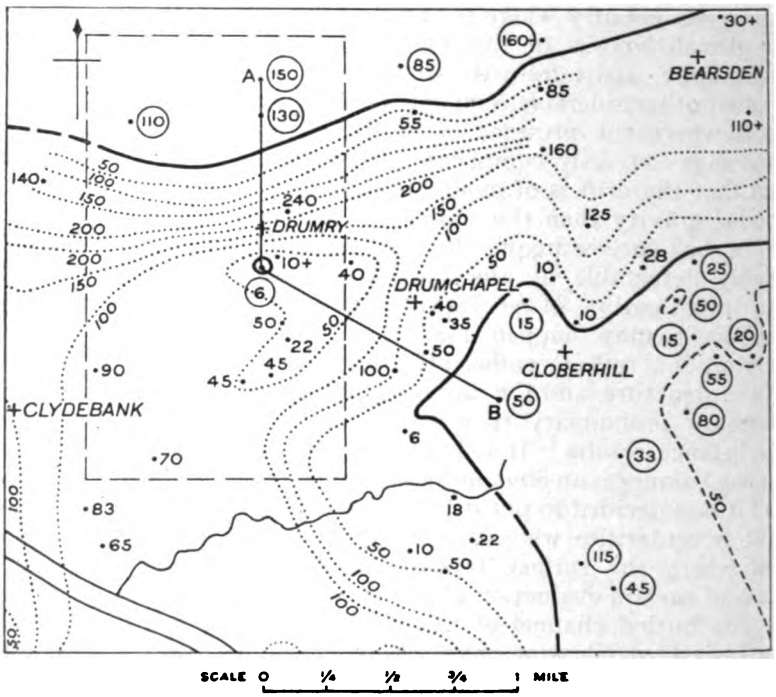

FIG. 1.—*Contour Map of the Rock Surface around Drumry after removal of the superficial deposits.*

·(25) *Height of rock surface in feet above ordnance datum level.*
·25 *Depth ,, ,, below ,, ,,*
·25+ *Depth below O.D. level, rock surface not reached.*
·(25)– *,, above O.D. ,, ,, ,,*
------ *Contours in feet above O.D. level.*
..... *,, ,, below ,,*
— — *Ordnance datum (present mean sea level).*
Inset is the area shown in FIG. 3.

the district around Drumry. The contours are in feet referred to ordnance datum level and are plotted from the data yielded by the borings whose sites are marked on the map. The map clearly shows the deep channel north of Drumry and the steeply sloping mass of

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rock rising through the drift, but nowhere reaching the surface, to the south of that place. The deep channel is shown as extending to the west for a distance of at least one mile, an inference based on one record of the depth of drift obtained from a mine working and indicated on the north-west edge of the figure.

The drift covering these ancient topographic features consists of clays and sands with an average specific gravity at the surface of 1·72 whilst the underlying sandstones, shales, ironstones and

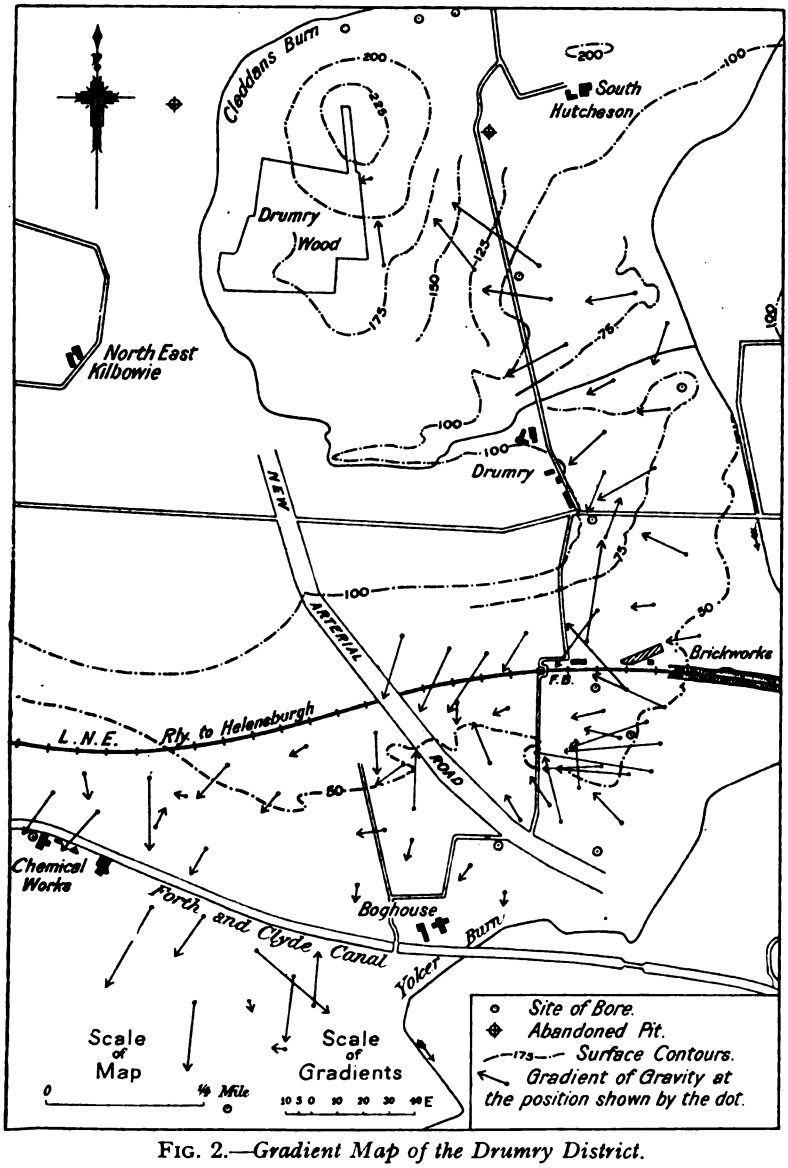

FIG. 2.—*Gradient Map of the Drumry District.*

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coals, belonging to the Coal and Ironstone Group of the Carboniferous Limestone Series, have an average specific gravity of, approximately, 2·38. There is consequently a density difference amply sufficient to render measurable the gravity anomalies arising from the irregularities of the surface between drift and rock. The objects of the survey were to determine the configuration of the rock-mass to the south of Drumry and to investigate the trend of the buried channel to the north by the method of traverse across its inferred strike.

GRAVITATIONAL RESULTS

(1) The Rock-mass South of Drumry.—Fig. 2 shows the gradients of gravity corrected for normal, terrain and topographic effects, with surface contours at intervals of 25 ft. to indicate the type of topography in the areas where topographic corrections were necessary. Fig. 3 shows the gradients and the isogams, *i.e.* lines of equal gravity anomaly, constructed from them, in the most critical part of the area surveyed. The presence of the rock-mass south of Drumry is clearly demonstrated by the consistent group of gradients directed westwards, and the isogams give some idea of its shape and dimensions. An inspection of the results plotted on the two figures shows (*a*) that the rock-mass has a steep eastern face; (*b*) that this face is incised in places; and (*c*) that the rock-mass is a ridge, with an irregular upper surface, extending westwards for a considerable distance.

(*a*) The steep eastern face is qualitatively shown by the large gradients directed westwards and the closely packed parallel isogams which are roughly comparable with the contours of the surface between rock and drift. By graphical and mathematical methods it is possible to calculate the slope of this face and to estimate the depth of its top from the surface. In the lower part of Fig. 4 is shown (1) the experimental curve formed by plotting the values of the average gradients along the line AB, Fig. 3, against the distance; (2) the theoretical curve of gradients, similarly obtained, due to a buried bank with a slope of 10°, as shown in the upper part of the figure; (3) the curve of difference between these two. This difference may be accounted for by assuming that the top of the bank, instead of being horizontal (dotted line) rises gently to the west as a slope of 2½° (continuous line). If now we plot the gradients due to the wedge-shaped mass lying between the continuous and the dotted lines the points shown by circles are obtained. These points practically coincide with the difference curve and hence it may be inferred that the gravitational effects are due to a westward rise of the rock-mass in the manner illustrated in Fig. 4; that is, the surface between rock and drift rises quickly from the east as a slope of 10°, flattens for a short distance and continues to rise more gently westwards as a slope of 2½°.

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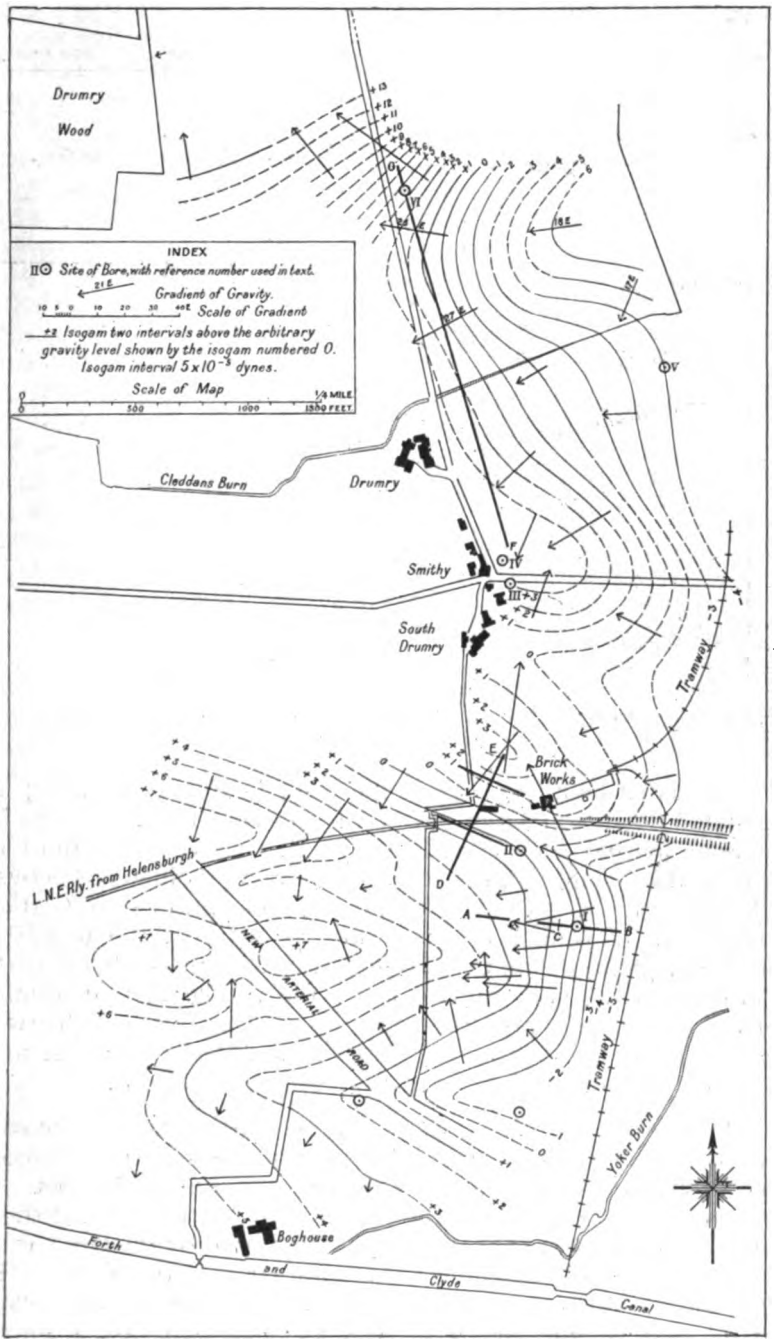

FIG. 3.—*Map showing Gradients and Isogams around Drumry.*

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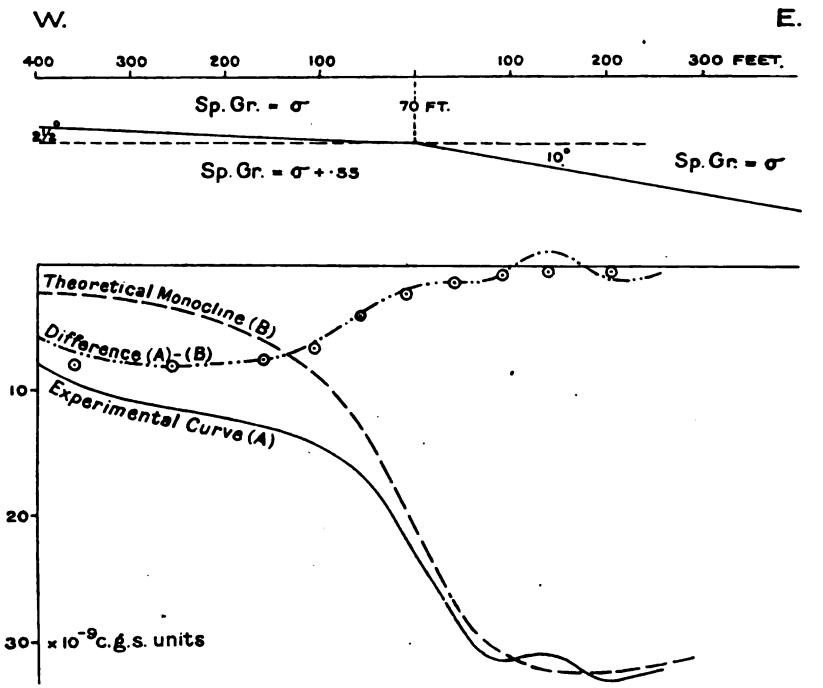

FIG. 4.—*Structure, theoretical and experimental gradients along the line A B of* FIG. 3.

The calculated depth to rock at the point C, Fig. 3, is 70 ft.; the calculated depth to rock at the position of bore I, Fig. 3, is 80 ft.; the bore journal showed rock at 74 ft. These calculations are made on the assumption that the specific gravity difference between rock and drift is ·55. The average specific gravity of Carboniferous rocks of similar type to those recorded in the journal of bore I is 2·38 and thus the specific gravity of the drift calculated from the gravitational results is 1·83; the average of 13 determinations at the surface gave the value 1·72. This difference between the calculated and determined values is doubtless partly due to an increase in the density of the drift at increasing depths.

(*b*) The isogams, Fig. 3, show that the eastern face of the rock-mass is incised in three places, the most marked of these incisions being the one immediately south-west of the brickworks. By methods similar to those mentioned above it can be deduced that a drift-filled hollow exists in the position indicated by the two parallel lines drawn perpendicular to the line DE on the figure. The approximate calculated dimensions of this hollow are, width 200 ft., and possible depth to rock 150 ft. Bore No. I showed rock at a depth of 74 ft. and bore No. II, south-west from the brickworks showed rock at a depth of 114 ft.; the gravitational

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and boring evidence are thus in essential agreement, although the gravitational interpretation of the buried topography is different from that shown on the map, Fig. 1.

(*c*) The westward extension of the rock-mass is shown by the isogams, Fig. 3; they also indicate that there is a gentle but persistent rise to the south and west. As a result of this approach of the rock to the surface small irregularities in the form of local knobs and hollows will cause considerable local variations in gradient both in magnitude and direction. Reference to Fig. 2 shows that such rapidly changing gradients were encountered in the south and west of the area surveyed. For example, to the north of the Chemical Works the gradients indicate a rock knob south of the railway with a hollow on the south succeeded by a rise still farther south towards the canal. At the Chemical Works itself a bore shows 116 ft. of drift. These local heights and hollows may be compared with the deep hollow south-west of the brickworks described above and show clearly that for a thorough investigation of a shallow buried topography a very close network of stations is necessary.

(2) The Buried Channel North of Drumry.—The map, Fig. 1, shows a deep channel north of Drumry continuing westwards for a distance of at least one mile. This western extension is deduced from the evidence of an isolated record of a depth of 140 ft. of drift shown on the extreme western side of the map. From what has been said above regarding the rapid local variations in the buried topography of this district it is clear, therefore, that the inferred western extension of the deep gorge is conjectural and it was decided to test the matter by a north-south traverse across the presumed strike of the channel. The results plotted on Figs. 2 and 3 show that there is no gravitational evidence for the existence of a deep gorge to the west. The magnitude and direction of the gradients and the trend of the isogams indicate clearly that the buried channel does not continue westwards but bends sharply to the south about ½ mile north of Drumry. The consistent westerly trend of the gradients and their magnitude point to the existence of a western bank which appears to be a northern continuation of the rock-mass south of Drumry. This bank stretches to the north of Drumry for approximately ½ mile and there, as shown by the course of the isogams, bends sharply to the east. The boring positions are shown on Fig. 3. Bores III and IV disclosed drift of a thickness of 93 feet and 120 feet respectively, but no rock was reached in either of them. At bore V rock was reached at 298 ft. and at bore VI the depth to rock was 132 ft. The thickness of drift is referred to the surface of the ground at each bore site whose heights above ordnance datum can be obtained from the contoured map, Fig. 2.

A diagrammatic representation of the course of the buried channel on the two hypotheses is given in Fig. 5 (*a*) and (*b*), the

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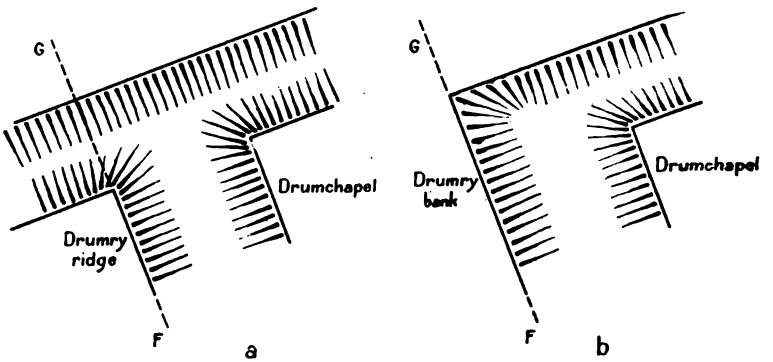

FIG. 5.—(a) *Diagrammatic representation of the buried Kelvin Channels according to the contour map of the rock surface, in the Glasgow Memoir.*

(b) *Diagrammatic representation of the bend in the buried Kelvin Channel according to the gravitational survey.*

line FG in both cases corresponding to the line FG on Fig. 3. If the channel runs as in Figs. 1 and 5 (*a*) then it can be shown that the maximum westerly gradient obtainable in a traverse across the northern channel is approximately 10 E. (=10 Eötvös units = $10 \times 1 \times 10^{-9}$ C.G.S. units). A gradient of 26 E. towards the west was actually measured in the field. By similar calculation it can be shown that on the second hypothesis, the theoretical maximum westerly gradient is approximately 32 E. whilst above bore V, the deepest known part of the channel, the theoretical gradient is 11–12 E.; these values are of the same order as the gradients determined from balance readings in the field. The gravitational evidence is thus definitely against a western extension of the northern channel. Apart from the mathematical analysis given in detail in the paper quoted (p. 1) it is proper to point out that the hollow known from the boring evidence to exist south of the brickworks (see above) was clearly demonstrated by a westward indentation of the isogams; a much more pronounced indentation of the isogams would have shown up the conjectured western extension of the northern channel had it existed. The isogams, however, show no westward indentation but swing sharply to the north and east. The qualitative results therefore point to the representation in Fig. 5 (*b*) as being the correct one and it has been shown that the values of the gradients calculated on that assumption agree with those determined by field measurement.

CONCLUSIONS REGARDING THE VALUE OF THE METHOD

The results described show that gravitational survey by means of the torsion balance is of considerable value for mapping sub-drift topography. The method adopted in the present instance,

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namely, to obtain confirmatory gravitational evidence of the existence of features known from borings and then to extend the survey into the unproved areas, illustrates one of the most useful ways of employing the balance. In many areas in this country our knowledge of subdrift topography is extremely limited and boring is a costly business. If the rock-surface below the drift is highly irregular, the scanty information derived from widely separated isolated borings is by no means sufficient to interpret the topography of that surface with accuracy, and an interpretation based solely on such evidence may, as already shown, prove untenable.

In such cases the gravitational method may be usefully employed to extend and supplement the boring evidence and for this purpose it is both cheaper and quicker than the drill.

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II.—A GRAVITATIONAL SURVEY OVER THE PENTLAND FAULT, NEAR PORTOBELLO, MIDLOTHIAN, SCOTLAND

BY

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Text-figures 1 to 10

INTRODUCTION

The mapping of concealed geological structure by the method of gravitational surveys with the Eötvös Torsion Balance depends on the fact that in most geological structures lighter and heavier rocks are brought into juxtaposition in such a way that the surface of separation between the two is inclined to the horizontal. Previous tests with the torsion balance have been carried out by the Geological Survey in areas where the nature of the lighter and heavier rocks was already well known from the geology and where the surface of separation was known to be inclined to the horizontal;[1] in the case of the Swynnerton dyke a steeply inclined mass of heavy basalt pierces horizontally bedded Keuper Marl of low specific gravity, whilst at Drumry loose sands and clays overlie a highly irregular pre-Glacial topography carved out of Carboniferous sediments of much higher specific gravity. In both instances it was found possible by means of the balance to determine the positions and boundaries of the concealed heavier rock masses and to calculate depths and slopes.

In areas composed of ordinary sedimentary rocks that have been folded or faulted the older rocks are usually denser than the younger and consequently anticlines and domes show an excess of gravity above their axes, whilst synclines and basins show a deficiency; similarly, in an area intersected by a large fault there is an excess of gravity on the upthrow side, that is, the side on which the older rocks are brought nearer the surface. It is thus possible under suitable conditions to use the balance to determine lines and axes of geological structure in districts built up essentially of sedimentary rocks where the solid geology is concealed by drift.[2]

Of the structures of common occurrence a steeply inclined fault is perhaps one of the most suitable for investigation by the gravitational method since, owing to the high inclination of the surface separating the lighter from the heavier material, it should

[1] 'A Gravitational Survey over the Swynnerton Dyke, Yarnfield, Staffs.', 'Summary of Progress' for 1927, pt. ii, (*Mem. Geol. Surv.*), 1928, pp. 1-14. 'A Gravitational Survey over the Buried Kelvin Valley at Drumry, near Glasgow,' *Trans. Roy. Soc. Edin.*, vol. lvi, part 1 (No. 7), 1929, pp. 141-155.

[2] 'The use of the Torsion Balance in the Investigation of Geological Structure in South-West Persia,' 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, pp. 168-196; J. H. Jones and R. Davies, 'The Measurement of the Second Derivatives of the Gravitational Potential over a Buried Anticline,' *Monthly Notices of Roy. Astron. Soc., Geophys. Suppl.*, vol. ii, no. 1, 1928, pp. 1-32.

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be readily detectable by a short traverse at right angles to the strike. The survey described in the present paper was undertaken to test the practical value of the method in detecting a fault in drift-covered country.

There are few published accounts of the results of such surveys. Barton[1] gives a short description of the results of a traverse across the Luling fault, Caldwell County, Texas, and also mentions the reported successful location of faults by the torsion balance in the Panuco district of Mexico, although no published details are available.

The fault selected for investigation is the well-known Pentland Fault, a powerful dislocation of great importance in the Edinburgh district. The course of this fault, although it is never actually exposed, can be mapped with accuracy for several miles; its trend is N.N.E.-S.S.W. At the northern end for a distance of two miles between Craigmillar and Portobello, on the Firth of Forth, its course is completely obscured by glacial and raised beach deposits, In this area the geological map, one-inch Sheet 32, Scotland, shows the lower horizons of the Calciferous Sandstone Series brought against the higher beds belonging to the Oil-Shale Group, of the same series. The site of the survey lies about one mile south of Portobello where the inferred course of the fault passes under the deposits of the 100-foot Raised Beach. The terrain is moderately flat and the superficial deposits are, as far as is known, of homogeneous character and uniform in thickness.

The geology of the district, shown in Fig. 1, is reproduced from the six-inch Geological Survey map, Edinburgh 4 S.W., published 1906, and amended in accordance with the new solid edition of the one-inch map, at present being engraved. The only exposures of rock are north of Duddingston Loch and at the positions shown by the dip arrows on the south and east of the map. The remainder of the area is covered by drift and alluvium, and the course of the fault, the outcrops and the geological boundaries are inferred from the general structure of the district. There is a considerable amount of mining evidence regarding the nature and disposition of the rocks on the east, or downthrow, side of the fault. Definite stratigraphical horizons have been recognised and the strata dip at high angles towards the east. Practically nothing is known regarding the rocks on the west, or upthrow, side of the fault. In this connection the extent and thickness of the basic volcanic rocks of Arthur's Seat[2] are of importance. At their outcrop, about 1½ miles west of the line of the fault in the area surveyed, these rocks have a thickness of about 1,000 ft. On the old edition of the one-inch Geological Survey map, Sheet 32, the eastern limit of

[1] Barton, D. C., 'The Eötvös Torsion Balance Method of Mapping Geologic Structure,' *Am. Inst. Min. Met. Eng.*, Technical Publication No. 50, 1928, p. 37.

[2] Arthur's Seat is a prominent hill lying ½ mile N.N.W. of Duddingston Loch (Fig. 1).

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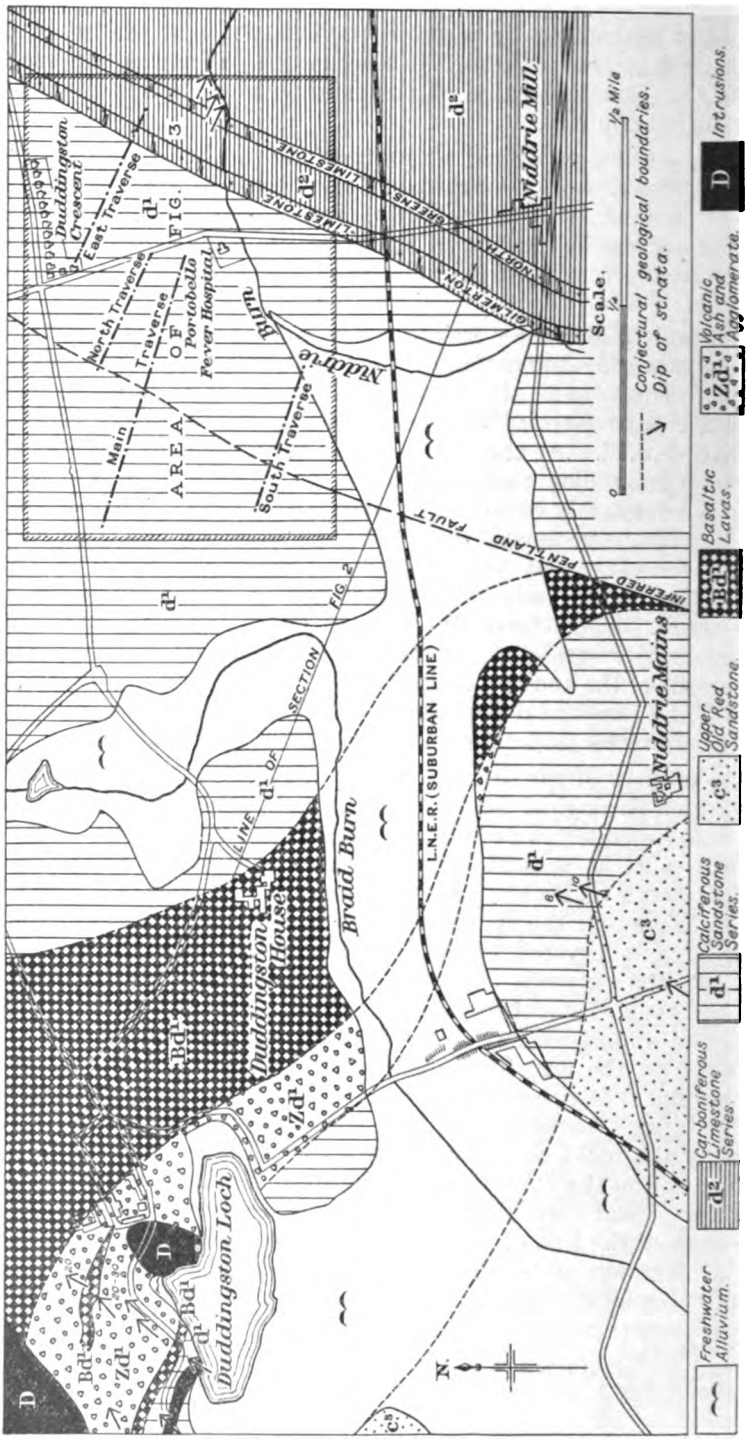

FIG. 1.—*Geological Map of the district south of Portobello; inset is the area of the torsion balance survey.*

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their outcrop lies about ½ mile west of the fault ; on the new edition at present being engraved they are inferred to come up to the fault (Fig. 1) but to be much thinner there than on Arthur's Seat. This view is also illustrated in the section (Fig. 2) prepared by the Geological Survey for the construction of a geological model

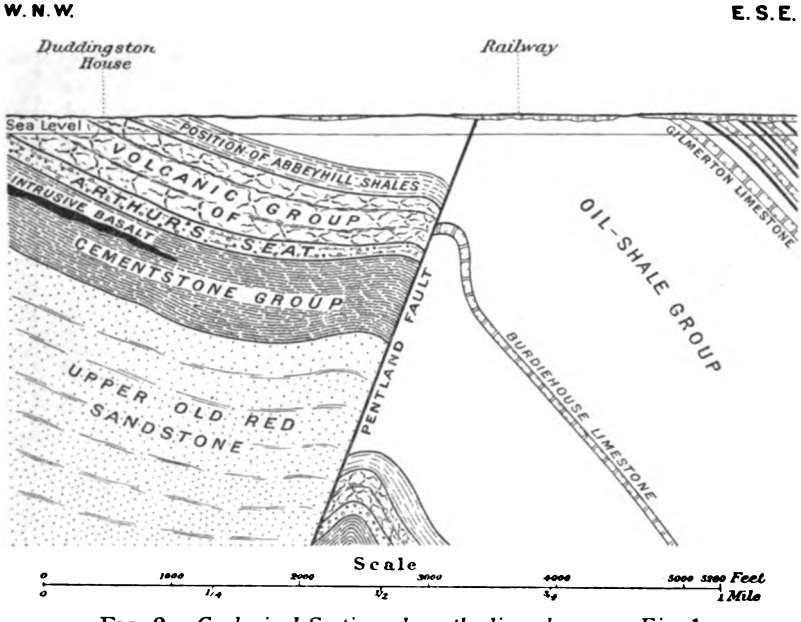

FIG. 2.—*Geological Section along the line shown on Fig.* 1.

of the district. The section shows the lavas, 500 ft. thick, reaching the fault at a depth of 600 ft. The complete absence of outcrops or boring information renders any interpretation conjectural.

The Pentland Fault is generally considered to be a steeply inclined reversed fault or overthrust, and, in the event of a thick series of heavy basic lavas being brought against much lighter sedimentary rocks along such a steeply inclined interface, large gravitational effects are to be anticipated. If, on the other hand, the lavas die out at a considerable distance from the dislocation, which in that case would bring sediments of slightly different age into juxtaposition down to a depth of at least 2,000 ft., then there might still be sufficient difference in specific gravity between the younger rocks on the east and the older rocks on the west to yield the gravitational effects necessary to map the plane of discordance.

Operations were begun in October, 1928, and continued till the end of December. In all, 53 stations were determined by visual observation at night.

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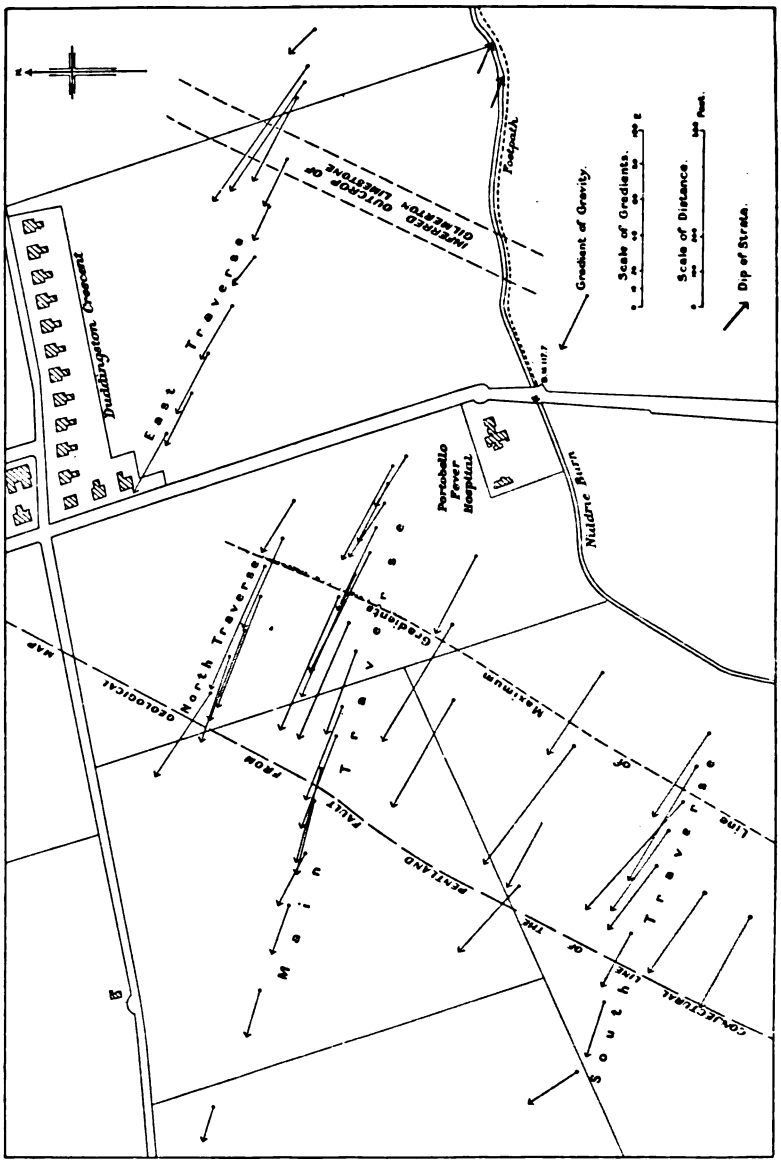

FIG. 3.—*Chart of residual gradients.*

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RESULTS OF THE TORSION BALANCE SURVEY

Four traverses were made with the balance across the inferred strike of the structure and additional observations were made at critical positions in the area between the main and south traverses. The results are plotted on the map, Fig. 3, which shows the magnitude and direction of the residual gradients of gravity determined at 53 stations. The outstanding features are the general parallelism of direction of the gradients on each traverse and the complete absence of reversal, all the gradients being directed towards the west-north-west. The largest gradients are found along a line nearly parallel to, and 180 yards east of, the conjectural line of the fault. East and west of this line the gradients fall off rapidly; the variation in their value along each line of traverse is shown graphically and more clearly in Figs. 4, 6, 7 and 8.

The constant west-north-westerly trend and the type of variation of the gradients indicate that a heavy subterranean mass of rock lies to the west and that the surface separating it from the lighter rocks to the east is very steeply inclined to the horizontal, that is, the structure is probably a fault. From theory, the strike of such a structure ought to follow very closely the line of maximum gradients, whose course is shown on the map, and the average direction of the gradients along each traverse should therefore be at right angles to that line. The following table shows how closely the experimental results of the survey confirm this expectation.

	South Traverse	Main Traverse	North Traverse
Direction at right angles to the average gradient direction	34½° E. of N.	24° E. of N.	22½° E. of N.
Direction of line of maximum gradient = strike of fault	30° E. of N.	25° E. of N.	22° E. of N.

Qualitatively, therefore, the gravitational measurements clearly indicate the presence of a fault very close to the position previously inferred from the general geology.

There follows a detailed examination of the results on each traverse and an attempt is made to supply a quantitative interpretation in accordance with what is known of the geology of the district. The stations on the east traverse lie wholly east of the fault but, along the strike, overlap the eastern stations of the main traverse. They were determined in order to carry the observations into ground where the nature and dip of the strata are definitely known. The gradients are directed a little more to the north than those in the traverses to the west and are practically at right angles to the known strike of the rocks; a detailed interpretation is given below.

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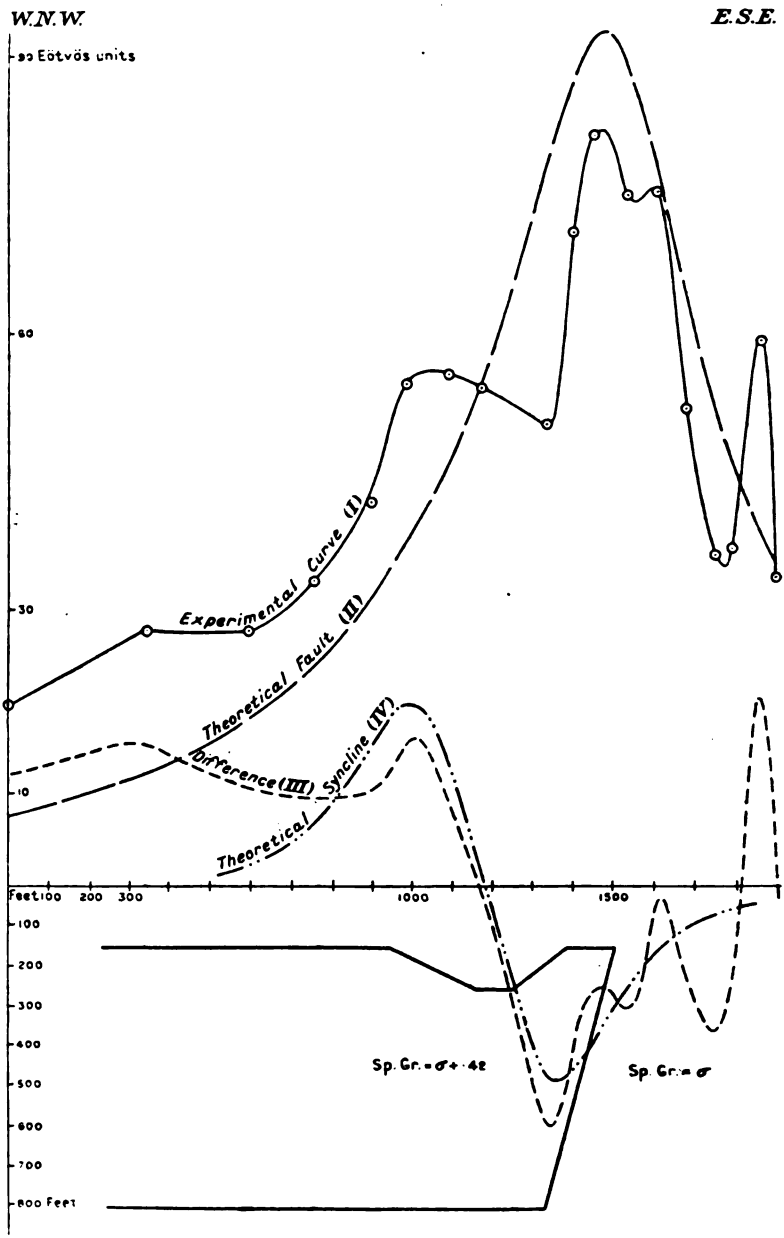

FIG. 4.—*Main Traverse. (I) Curve of gradient components parallel to traverse; (II) Theoretical curve of gradients due to the fault shown in lower part of figure; (III) Curve of difference between (I) and (II); (IV) Theoretical curve of gradients due to syncline as shown.*

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The Main Traverse.—Fig. 4 shows in graphical form the variation in value of the gradients along this line. In this and subsequent figures the values plotted are the components of the gradients along the average gradient direction of each traverse, positive ordinates representing gradients directed W.N.W., and negative ordinates those in the reverse direction. The experimental curve (I), Fig. 4, clearly arises from a fault-like structure but marked irregularities indicate that, in addition to the fault, minor structures are present. The theoretical curve (II) drawn for the fault-block with the position, thickness and specific gravity difference indicated in the lower part of the figure bisects roughly the irregularities in the experimental curve and may be taken as a first approximation to the main structure. The difference between the two curves is shown graphically in curve (III). It may be largely accounted for if we assume that the rocks immediately to the west of the fault-plane are folded into an asymmetrical syncline of the dimensions indicated. Curve (IV) shows the values of the gradients calculated for this syncline.

The final difference between the experimental gradients and those due to the fault combined with the syncline are plotted on Fig. 5. Quantitative interpretation of these differences is

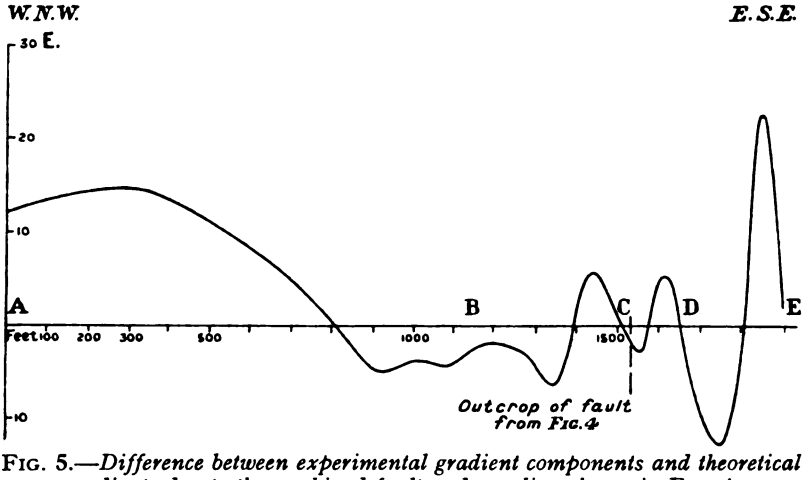

FIG. 5.—*Difference between experimental gradient components and theoretical gradients due to the combined fault and syncline shown in* FIG. 4.

impracticable but they suggest qualitative deductions that are geologically probable. The residual gradients from B to A point to a flattening of the dip of the western flank of the syncline and to a continued westward rise of the dense rock. The small rapidly changing residue between B, C and D is probably to be correlated with intense folding and with irregularities in the rock-drift interface in the immediate neighbourhood of the fault. The part of the curve between D and E may bear two interpretations. First, it may be due to a local rock-knob rising through the drift; in

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this event the traverse has so cut across it that the direction of the gradients is not altered (see Fig. 3). Second, it may be due to the existence of a narrow, very steeply inclined heavy stratum, parallel to the fault. If such a stratum were continuous along the strike we should expect it to cause similar variation in the values of the gradients at the western stations of the east traverse (see Fig. 3). Although there is some marked irregularity at these stations (see Fig. 8) sufficient observations have not been made to show whether the large and rapid variations under discussion are there reproduced in detail; comparison of the magnitude of the gradients and the distance between the stations shows that their occurrence is possible. It may be noted that if the variations between the positions D and E (Fig. 5) are due to a heavy stratum then, from the asymmetry of the curve, it dips towards the west—that is, like the fault itself, the strata immediately east of the fault-plane are reversed.

So far no reference has been made to the magnitude of the throw of the fault, in other words, to the position of the heavy block on the east or downthrow side of the fracture. All the evidence available from mining and from exposures near the fault shows that on the east the strata are very steep. Hence the heavy block on the west must occur on the east as a very acute, almost vertical wedge lying against the fault-plane (cf. Fig. 2.) If the top of this wedge lies at 1,000 feet from the surface, that is, the throw of the fault is 850 feet, its gradient effect does not exceed about 6E. within 500 feet on either side of the fault. Thus within the critical area of the survey we may consider the interpretation advanced above to be valid on the assumption that the throw of the fault is at least 850 feet; how much more it may be we cannot say.

The North Traverse.—The results obtained here are of the same type as in the main traverse. The value of the maximum gradient is lower, however, and this may point to the lowering of the heavy block by pitch towards the north-north-west. Such a pitch is known from geological evidence to be the case, but in view of the number of complications in the vicinity of the fault we do not stress this decrease in maximum gradient as a direct gravitational proof of pitch.

It is to be noted that the distance between the maximum and minimum turning values on the curve (Fig. 6) is 280 ft.; the corresponding points on the curve for the main traverse (Fig. 4) are 150 feet apart. We may conclude, therefore, that the east flank of the syncline west of the fault is 130 feet farther west in the north than in the main traverse. This indicates that the syncline probably strikes more directly north and south than does the fault.

The South Traverse.—The experimental gradients are shown by the curve (A), Fig. 7. This curve is steeper on the west than on the east and to that extent indicates that the gradients are due to a

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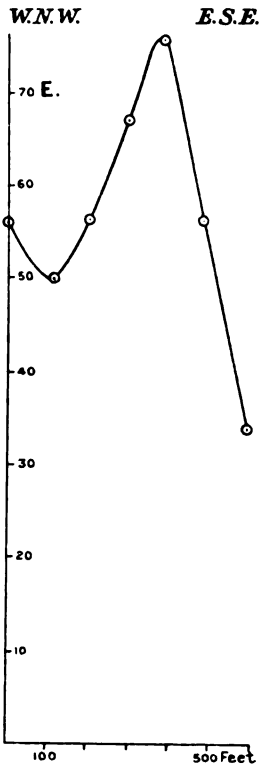

FIG. 6.—*Gradient components along north traverse.*

normal fault hading towards the *east*. A steep normal fault structure, with very large throw, can easily be found, which will yield a gradient curve almost coincident with the critical part of the experimental curve ; the position and dimensions of the block on the west would be, in that case, depth from surface 60 feet, thickness of block about 720 feet, with a specific gravity ·22 greater than the lighter rocks on the east. If, however, we attempt to interpret the results along the main traverse by a similar structure large gradients remain which cannot be explained by assuming any subsidiary structure which is geologically probable.

On the other hand, if we assume the fault to be reversed and the heavy block on the west to lie at 120 feet from the surface, to have a thickness of approximately 680 feet, and a specific gravity difference of ·42, we obtain the theoretical curve (B). Curve (C) shows the difference between curves (A) and (B). This difference can be readily explained, as shown in Fig. 7, by assuming a steep westerly dip of the heavy strata away from the fault—that is, a minor structure of monoclinal type. Curve (D) shows the calculated values for this structure. It is practically coincident

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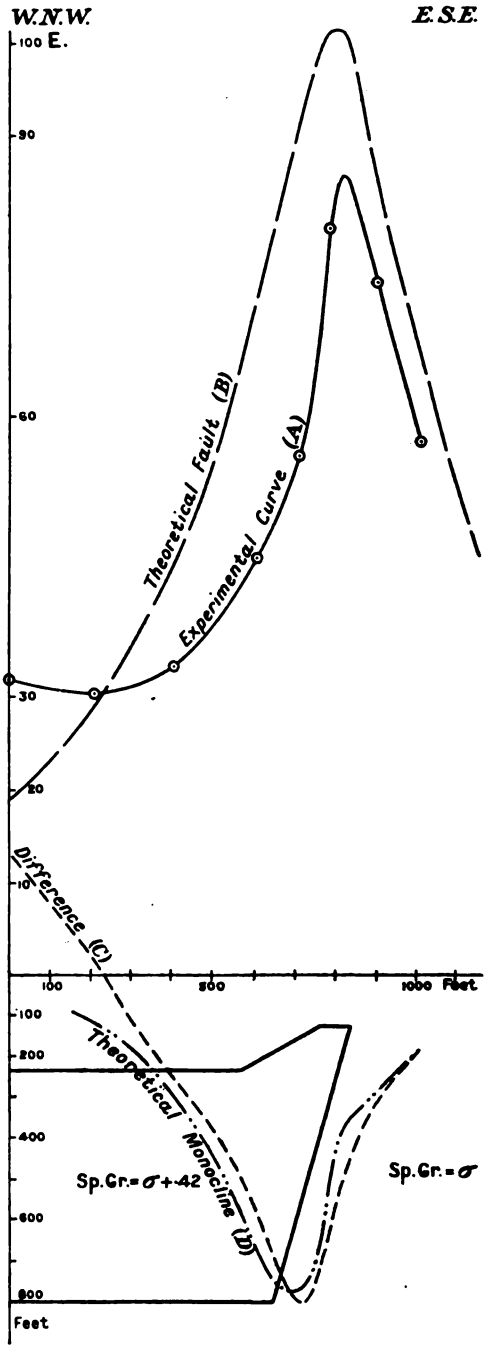

FIG. 7.—*South Traverse. (A) Curve of gradient components parallel to traverse; (B) Theoretical curve of gradients due to the fault shown in lower part of figure; (C) Curve of difference between (A) and (B); (D) Theoretical curve of gradients due to the monocline shown in lower part of figure.*

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with the difference curve (C) over the critical area and, as in the main traverse, arises from a structure which is geologically probable. There still remains a considerable difference at the western end of the traverse, accountable as before (p. 17) by a gradual rise of the heavy rock towards the west.

The East Traverse.—Owing to the existence of the deep channel of the Niddrie Burn the main traverse could not be extended farther east than as shown on Figs. 1 and 3. North-east of the main traverse a line was therefore selected which would afford a series of practically collinear stations, overlapping on the west the eastern stations of the main traverse and enabling observations to be extended uninterruptedly eastwards into an area where the structure can be fairly definitely inferred from quarrying and mining evidence. As shown on Fig. 3, the line crosses the inferred outcrop of the Gilmerton Limestone, a band 60 feet thick in places and in this area taken as the base of the coal-bearing series. As the strata are highly inclined, and compact limestone has a comparatively high specific gravity, it was hoped to confirm the position of the Gilmerton Limestone from the balance results.

The traverse yielded a series of parallel gradients (Fig. 3) which are directed a little more north of west than the gradients of the north and main traverses. This is probably due to the strike of the strata being a little more east of north than the strike of the fault. Fig. 8 shows the curve of gradient components along this traverse. Numerically we find that the western stations yield approximately the same values as the eastern stations of the main traverse but without the rapid variation there noted. We have already pointed out, however, that the occurrence of such rapid variation of gradient must not be excluded as impossible since the stations are fairly wide apart. About the middle of the east traverse the gradients decrease in magnitude rapidly to a minimum value while retaining their direction. If this decrease is due to the existence of a bed of heavy limestone, 60 feet thick and dipping towards the east at 45°, the approximate position of the centre of the bed is as shown in Fig. 8. This position is 135 feet west of the inferred outcrop of the Gilmerton Limestone. At the east end of the traverse the gradient curve rises very steeply to a peak and falls again very quickly. The type of curve, the small distance over which the gradients vary so rapidly and the deflection of the gradients as shown in Fig. 3, suggest the presence of a subdrift feature at shallow depth in this locality. On the assumption that the general westerly gradient due to the fault combined with easterly dip of the strata, is here about 20 E., the feature may be interpreted as a rock cliff of 40 ft. buried under 20 ft. of drift whose specific gravity is ·6 lower than that of the rock. The calculated thickness of drift west of the position of maximum gradient is therefore about 20 ft., while on the east it is 60 feet. Very little is actually known about the

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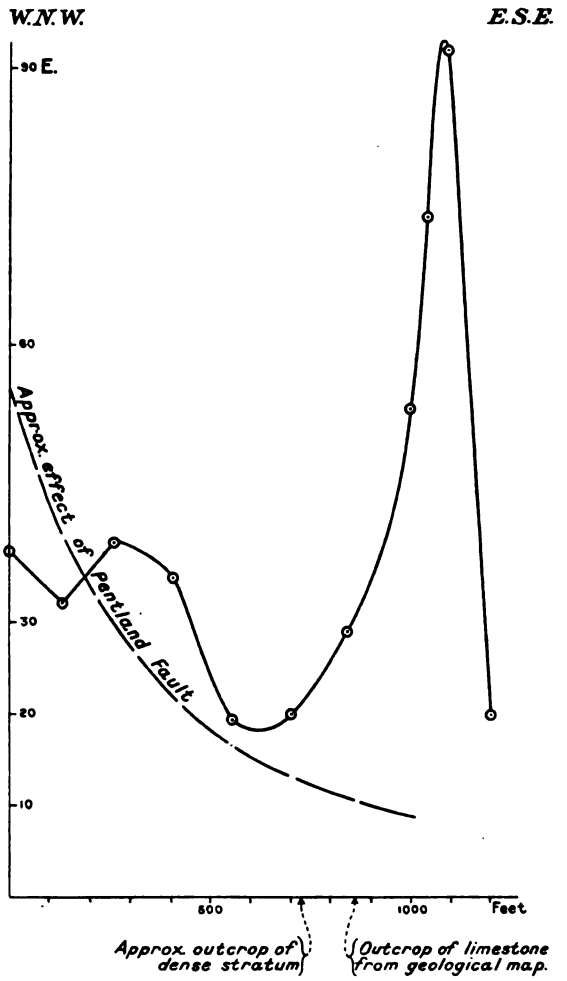

FIG. 8.—*Gradient components along east traverse.*

depth of drift in this area, but 150 yards to the south, rock is exposed in the Niddrie Burn (Fig. 3) which is here only 20 feet below the level of the stations in question.

Curvature values.—The determination of residual curvature values due to sub-surface structure demands topographic corrections much more detailed and extensive than in the case of gradients. In the present instance a considerable part of the area was contoured at 5-foot intervals, and topographic corrections were calculated up to a distance of 2,000 feet from most of the station points. From 2,000 to 10,000 feet corrections were similarly applied by the net method, using the 25-foot, 50-foot, and 100-foot contour intervals on the six-inch maps. The residual curvature vectors

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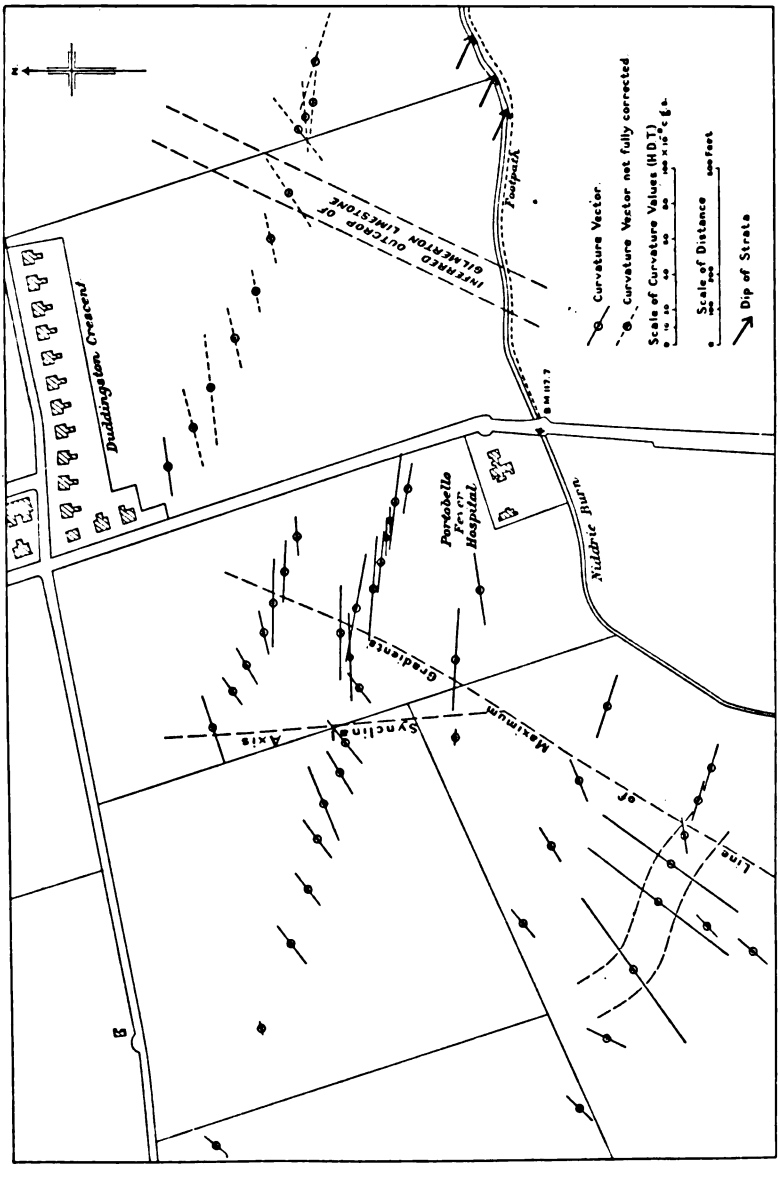

FIG. 9.—*Chart of residual curvature vectors (H.D.T.).*

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due to the structure, after application of the corrections so obtained, are plotted on Fig. 9. From theory they ought to lie parallel to the fault on the upthrow side and at right angles to it on the downthrow side[1]; this is well brought out on the chart, Fig. 9, which also shows that the change in direction takes place approximately along the line of maximum gradient. In the neighbourhood of the synclinal axis deduced from the gradients (p. 17) the curvatures show a distinct departure from the N.N.E. direction and tend to lie across this axis; this again is to be expected from theory.[2]

The three anomalously large curvature values shown in the south traverse require explanation. They lie parallel to the fault but their values are more than twice as great as those calculated for the structure inferred from the gradients. It is to be noted that these large values fall away very suddenly at neighbouring stations, whilst the most westerly of the three shows a distinct change in direction; further, the gradients at the stations in question are not anomalous (see Fig. 7). The facts suggest that the structure causing the anomalous curvature vectors is a shallow one. A drift-filled channel, whose course is shown in the diagram by dotted lines, 120 feet wide, 40 feet deep, and buried under 20 feet of drift, would produce curvature values of about 60 E. at points above its deepest part where the gradient is zero. At points nearly above the top of the channel banks the gradients would reach their maximum value of 13–14 E. and beyond the channel both gradients and curvature values would be small. These effects when combined with the curvatures and gradients calculated for the structure already deduced for this traverse (Fig. 7) are of the order of the values measured in the field. It is of interest to note that a buried channel running E.–W. has been proved about ½ mile to the south.[3]

CORRELATION OF THE GRAVITATIONAL RESULTS WITH THE GEOLOGY OF THE DISTRICT

The interpretation of the gravitational results given above is based on the assumption that the heavy block on the west has a specific gravity higher by ·42 than the strata on the east or downthrow side. These strata are known to belong to the Calciferous Sandstone Series consisting of sandstones and shales with an average specific gravity of 2·4 determined from a series of specimens. The heavy block on the west therefore has a specific gravity of 2·82. The only known rocks west of the fault with such a high specific gravity are the volcanic group of Arthur's Seat, the mean value for which, as estimated by James,[4] is 2·75. The nearest visible outcrop of these rocks is about 1½ miles west of the fault,

[1] 'Summary of Progress' for 1926 (*Mem. Geol. Surv.*), 1927, p. 192.

[2] *Loc. cit.*, p. 191.

[3] Milne, D., 'The Midlothian and East Lothian Coalfields,' *Trans. Roy. Soc. Edin.*, vol. xiv, pt. i, 1839, pp. 313-4.

[4] 'Observations and Calculations of the Principal Triangulation of Great Britain,' 1858, p. 609.

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and the extent to which they stretch eastwards from that point was hitherto unknown (p. 13). On the geological model of the Edinburgh District in the Royal Scottish Museum they are shown as reaching the fault at a depth of 600 feet and retaining a thickness of 400 to 500 feet. The gravitational results have confirmed this eastern extension of the volcanic horizon up to the fault, and indicate that it lies at 150 to 250 feet from the surface and has a thickness of approximately 600 feet (p. 16). It must be emphasized, however, that these quantitative deductions are subject to qualification. They are based on the assumption that the gradient effects at the fault are due wholly to comparatively shallow structures, and this assumption probably does not hold. For example, at a depth of about 2,000 feet below the Arthur's Seat Group there occur the andesites, trachytes and rhyolites of Lower Old Red Sandstone age. At the fault these must be brought into juxtaposition with younger sediments of lower specific gravity. Such a deep-seated structure will give rise to a westerly gradient which will remain tolerably constant over the relatively small area surveyed; but as we know neither the throw of the fault nor the thickness of strata covering the Old Red Sandstone lavas the value of the gradient is unknown. Allowance for it would not affect the deductions already made regarding the types of structure but would alter the numerical estimates. Thus if we assume over the main traverse a constant W.N.W. gradient of 15 E. due to the deep-seated block, then the calculated dimensions and position of the shallower block are altered to thickness 400 feet, minimum depth from surface 200 feet, specific gravity difference about ·42; on these assumptions the minor structures already described would still be present but at correspondingly greater depth.

If some definite geological information were available, for instance, if the depth or the thickness of the Arthur's Seat lavas were known, more accurate quantitative deductions could be made from the balance results, and it would be possible to estimate an upper limit for the throw of the fault. Such evidence can only be obtained by boring or possibly by the application of alternative geophysical methods, for example the seismic method. The problem, in fact, illustrates the well-recognised principle that geophysical methods are complementary to one another and yield the most fruitful conclusions when they are jointly used in areas where there is a substantial basis of geological evidence to control the interpretation of the results.

SUMMARY

The structural map, Fig. 10, is based on the results of the gravitational survey which are summarized below.

(1) The variation in the gradients determined along a series of traverses clearly indicates the existence of a fault accompanied by minor folding.

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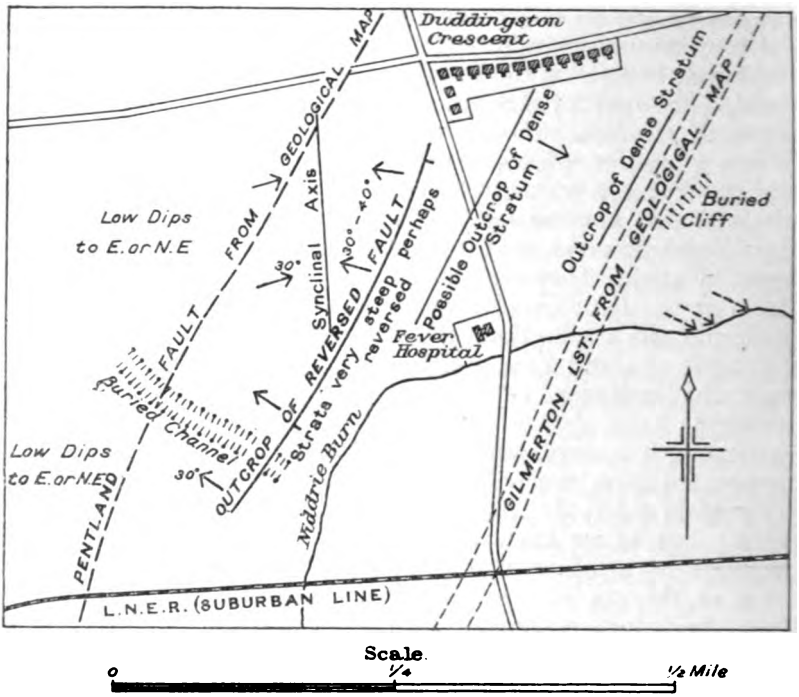

FIG. 10.—*Geological structure deduced from the gravitational survey. Lines and dips taken from the Geological Map are shown broken.*

(2) The maximum gradients on each traverse have a high value and lie on a line which is parallel to the line of the Pentland Fault as plotted on the six-inch Geological Survey map, and 180 yards east of it.

(3) The buried outcrop of the fault is close to the line of maximum gradient and its strike is at right angles, within 3–4 degrees, to the average direction of the gradients on each traverse.

(4) The fault is reversed and hades steeply towards the west or upthrow side; it strikes N.N.E.–S.S.W.

(5) The heavy horizon west of the fault is the Arthur's Seat lavas with a deduced specific gravity of 2·82. Their thickness estimated from the values of the gradients is 500–600 feet, and their depth below the surface at the fault is 150 feet; this depth is increased to fully 250 feet by sharp synclinal folding west of the fault. Reasons for possible qualification of these figures are given (p. 25).

(6) The strike of the minor folding west of the fault is deduced as almost due north and south.

(7) The strata immediately east of the fault are very steep and possibly reversed.

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(8) The strike of the sedimentary rocks deduced from the gradients along the east traverse is practically the same as the strike observed in the nearest exposures.

(9) The outcrop of a dense stratum, probably the Gilmerton Limestone, was located at 130–140 feet west of the inferred position of this limestone. The gravitational results in this area are so complicated that we doubt if this location would have been made unless the geology had been fairly accurately known.

(10) The absence of pronounced local anomalies in the gradients indicates that the surface between rock and drift is regular, as might be expected since it forms part of a raised beach. Abrupt local changes in the thickness of the drift are indicated at two places; in the one case the presence of a buried channel, in the other, a buried cliff, is suggested. The average depth of drift in the area surveyed appears to be about 20 feet.

(11) Quantitative deductions were not made from the residual curvature values, but in several respects these afforded a valuable qualitative check on the deductions made from the gradients. The existence of the shallow structure on the south traverse, which may be a buried channel, was shown by the curvatures and not by the gradients.

In conclusion we desire to acknowledge the kindness of Mr. Simpson of Duddingston Mains, and Mr. Grey of Niddrie Mains, who afforded us every facility for carrying out the investigation.

APPENDIX

Topographic corrections —Under this head were calculated surface effects between the distances 100 ft. and 2,000 ft. from the stations. The gradient effects were at most 1·5 E. but the curvature corrections varied greatly in magnitude and direction, the highest value being 24 E. The corrections were calculated by the network method explained by Shaw and Jones,[1] the nets used being such as are suitable for use with maps on the scale of 1 : 2500 or 25·344 inches to one mile. Equations for constructing the gradient net have been given in a previous paper.[2] The equations for construction of the curvature net are derived from the formulae for the effect due to a column of height z above the station point and lying between the azimuths θ_n and θ_{n+1} in the zone $\rho=\rho_m$ to ρ_{m+1}, namely

$$U_\Delta = -\tfrac{3}{2} G\sigma z \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\sin 2\theta_{n+1} - \sin 2\theta_n)$$

$$2U_{xy} = \tfrac{3}{2} G\sigma z \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\cos 2\theta_n - \cos 2\theta_{n+1})$$

In order to obtain a net in which the outer divisions were not too large we used two constants. For the five inner zones the constant chosen was

$$\left| \left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right) (\sin 2\theta_{n+1} - \sin 2\theta_n) \right| = \cdot 01$$

[1] Shaw, H., and E. Lancaster-Jones, 'The Theory and Practical Employment of the Eötvös Torsion Balance', *Mining Mag.*, vol. xxxvi, No. 6, 1927, pp. 339-340.

[2] McLintock, W. F. P., and J. Phemister, 'A Gravitational Survey over the Buried Kelvin Valley at Drumry near Glasgow,' *Trans. Roy. Soc. Edin.*, vol. lvi, part 1, 1929, p. 147.

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and for the remaining zones up to 2,000 ft. it was ·005. The radii and circles which intersect in the effect centres of the divisions of the network are then given by

$\pm\ \theta$ = 2° 52′, 8° 44′, 15°, 22° 13′, 32° 5′, 57° 55′, 67° 47′, 75°, 81° 16′, 87° 8′.

and

ρ = 105·2, 117·6, 133·3, 153·8, 181·7, 210·5, 235·3, 266·7, 307·5, 363·5, 444, 572, 800, 1333·3 feet.

An example illustrating the use of the method in calculating U_Δ and $2U_{xy}$ is given by Shaw and Jones in the paper referred to above. It must be remembered that the relative height of the surface with respect to the station point is measured in units of 100 feet.

Cartographic corrections were not made for gradients but were estimated at several stations for curvatures by the net method between the distances 2,000 ft. and 10,000 ft. (nearly 2 miles) from the station. Since the distances from the stations are now large each quadrant was divided up by eight radii instead of by five as in the nets for topographic correction. The constant value of $\left|\left(\frac{1}{\rho_m} - \frac{1}{\rho_{m+1}}\right)(\sin 2\theta_{n+1} - \sin 2\theta_n)\right|$ was chosen as ·001 so that the dots at each effect centre would be distinct on maps drawn on the scales of three inches to one mile (1 : 21,120) and six inches to one mile (1 : 10,560). The radii and circles which intersect in the effect centres of the divisions are given by

$\pm\ \theta$ = 1° 48′, 5° 24′, 9° 6′, 13°, 17° 6′, 21° 43′, 27° 10′, 34° 49′, 55° 11′, 62° 50′, 68° 17′, 72° 54′, 77°, 80° 54′, 84° 36′, 88° 12′.

and

ρ = 2,033, 2,101, 2,174, 2,252, 2,336, 2,427, 2,525, 2,631, 2,747, 2,873, 3,012, 3,333, 3,731, 3,968, 4,237, 4,545, 4,902, 5,319, 5,814, 6,410, 7,143, 8,065, 9,260 feet.

The net is used for calculating U_Δ and $2U_{xy}$ exactly as for topographic corrections but the height of the surface relative to the station point is measured in units of 1,000 feet.

Within the area surveyed the corrections varied numerically from 20 E. to 1 E., so that we cannot assume the curvature effects completely corrected even by calculation of surface effects up to a distance of two miles.

Formulae.—No new formulae were derived for gradient or curvature effects but the following simple equations may prove of use in estimating first approximations of depth and thickness of an infinite horizontal block with vertical edge :—

Let $\Delta^2 \equiv D$ = depth of bottom of the slab.

$\delta^2 \equiv d$ = ,, top ,,

l_1 = distance between position of maximum gradient and position where gradient is $\frac{3}{4}$ maximum.

l_2 = distance between position of maximum gradient and position where gradient is $\frac{1}{2}$ maximum,

then $(\Delta + \delta)^2 = l_2 + \frac{l_2^3}{l_1^2}$

and $(\Delta - \delta)^2 = \frac{l_2^3}{l_1^2} - 3l_2$

These equations may be compared with others dealing with the same problem given by Jones and Davies.[1]

These authors make use of the positions where the gradient is respectively one half and one quarter of the maximum value.

[1] Jones, J. H., and R. Davies, 'The Measurement of the Second Derivatives of the Gravitational Potential over a Buried Anticline,' *Monthly Notices of Roy. Astron. Soc., Geophys. Suppl.*, vol. ii, no. 1, 1928, pp. 25-26.

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III.—THE INVERBEG LAMPROPHYRE

By Sir John S. Flett, K.B.E., F.R.S.

On the west side of Loch Lomond about one mile south of Inverbeg Inn there is a well-known lamprophyre dyke exposed in a quarry by the roadside. This locality is 2½ miles north of Luss and 5 miles south of Tarbet. The dyke is about 16 feet thick, runs in a direction a few degrees south of west, and dips to the south at an angle of 75 degrees. Formerly this rock was extensively quarried as a roadstone for mending the local roads, but under present conditions the quarry seems to have been abandoned, though perhaps only temporarily. During a visit to the spot in 1928 I found that active work had not been carried on at least for a season or two. Consequently, fresh broken specimens, which were to be had in any number when first I visited the quarry in 1900, were now rather difficult to obtain.

The dyke is a reddish lamprophyre of a type which is not uncommon in the Southern Highlands and belongs to a group that is associated with the Newer Granites. Evidence of this affinity is provided by the occurrence of types of Newer Granite and Diorite which are strikingly like these lamprophyres. The whole series is presumably of early Devonian or late Silurian age; they are usually entirely free from metamorphism, a feature which distinguishes them from the granites and gneisses of the 'Older' group. This dyke is marked on the one-inch geological map, Sheet 38, with the index letter SM, which is supposed to have been derived from the old name mica-syenite, formerly sometimes applied to minette.

The country rocks into which the dyke is intruded are silvery-greenish schists rich in muscovite and chlorite, and sheared greenish grits which are developing into granulitic paragneisses. Two specimens (26736, 26737) taken from the rocks adjoining the quarry were sliced and examined with the microscope. In both the clastic origin of the rock is evident as they contain pebbles of quartz and felspar, which are large and obvious; they are surrounded by a matrix which has a parallel schistose structure owing to the abundance of fine scaly muscovite and green chlorite mixed with smaller quartz and felspar grains, irregular in shape but often arranged in lenticles parallel to the foliation. The minerals are, in approximate order of abundance, quartz, alkali-felspar, muscovite, chlorite and carbonates. The scanty accessories are iron ores, rutile, apatite, sphene, tourmaline and zircon. Here and there a small irregular flake of greenish-brown biotite makes its appearance. Garnet seems to be absent. Closer examination of the felspars reveals that they are practically all orthoclase and albite as every crystal showing plagioclase twinning has a lower refractive index than quartz and Canada balsam.

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The maps of this neighbourhood were revised by Mr. E. H. Cunningham Craig[1] who places this series in his Ben Ledi Group. He has given a description of their petrographical characters in his paper on Metamorphism in the Loch Lomond district. The special feature that concerns us at present is the low state of their metamorphism. These sheared grits of the districts adjoining the Highland border are recognised as coarse quartzo-felspathic sediments in which the obliteration of the clastic structures is only very incomplete and the development of new minerals has hardly progressed beyond the formation of a limited amount of white mica and clear albite.

Many of the larger pebbles of quartz are broken up into a mosaic of interlocking angular grains, though some have merely an irregular dappled extinction between crossed nicols that shows they are in a state of strain. The felspar pebbles are less frequently crushed. As a rule these larger elements of the rock have elliptical or lenticular shapes with their longer axes parallel to the schistosity.

The rock of which the dyke consists is a fairly typical lamprophyre of the vogesite group; its dominant minerals are felspar and hornblende with, in some specimens, a fair amount of biotite. The structure is of the 'panidiomorphic' type, as all the minerals, though never perfect, usually show well developed crystalline form. The state of preservation varies in different specimens but as a rule there is a good deal of decomposition. The greenish-yellow hornblende is often replaced by chlorite and epidote (?), the felspar is cloudy and filled with small micaceous scales, and the yellow biotite seldom gives its high polarization colours over the whole extent of a crystal. The exact nature of the felspar cannot always be determined but there is a considerable amount of untwinned felspar which is presumably orthoclase and a nearly equal amount of polysynthetic felspar which has a low refractive index indicating that it belongs to the oligoclase and albite series.

The special interest of this dyke, however, arises from the variety and number of its inclusions. These were strikingly evident in the debris of the quarry and might be collected in large numbers when the rock was being worked as road metal. The inclusions are seldom more than three or four inches in diameter and most of them are the size of a walnut or less. They may be divided into two groups,[2] the 'homoeogenetic' which consist of the same minerals as the igneous rock itself, and the 'enallogenetic' which consist of foreign or derived materials caught up by the igneous rock.

Belonging to the former class are certain reddish lumps that consist of felspar and hornblende in crystals considerably larger than those that form the groundmass of the rock. A section of

[1] 'Metamorphism in the Loch Lomond District,' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 10.

[2] Lacroix, A., 'Enclaves des Roches Volcaniques,' 1893.

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one of these masses shows that the main components are alkali-felspar, both simply twinned and polysynthetic, greenish-brown idiomorphic hornblende, a little yellow biotite and a few large crystals of albite. This, in fact, might be described as a coarsely crystalline vogesite and little difficulty would be found in accepting it as of purely igneous origin.

There is a good deal of evidence, however, to show that these crystalline masses of felspar and hornblende are connected with the absorption of foreign inclusions. Some of them are rich in biotite and towards their centres have fragments of undigested sedimentary schist. They seem to have arisen from the felspathization of a schist fragment, permeated by the magma of the rock (26732). One very instructive section (10194) shows a group of large felspar crystals containing two rounded corroded pink garnets. These garnets have a narrow black border, showing that they were undergoing absorption. They are apparently the last relics of a piece of garnetiferous schist which has been assimilated by the igneous rock. The same process though incomplete is shown by many of the recognizable schist inclusions, which have borders of varying breadth consisting of coarsely crystalline felspar. Only the smallest xenoliths have been completely digested and replaced by minerals similar to those of the lamprophyre itself.

Of the true xenoliths or foreign inclusions in the dyke there is a considerable variety; in fact, it would almost be true to say that no two are strictly similar and each presents characters indicating a different origin. Only twelve have been sliced for the purposes of this investigation and at present it is difficult to obtain more, but should the quarry be worked again some very interesting results might be expected.

Probably the commonest inclusions are rounded lumps of clear white quartz which no doubt have come from the quartz veins in the adjacent rocks of the Ben Ledi group. They are usually much rounded by solution. The other inclusions are nearly all greenish schists, dark in colour and fine-grained. Except that they show occasionally clear grey quartz and pink garnets as large as a barleycorn, there is nothing about them that is characteristic to naked eye inspection. Under the microscope, however, they show many features of interest.

Their original characters can in most cases be inferred only indirectly; they are usually much weathered and full of chlorite replacing biotite, hornblende, etc. Besides, they have often suffered contact alteration accompanied by a considerable amount of magmatic assimilation.

Fragments having large rounded quartz grains enclosed in a schistose matrix of quartz, felspar and chlorite (10192, 26734) are probably derived from the Ben Ledi schists and grits of the immediate neighbourhood.

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Another fragment (12913) has the characters of a hornblende-schist. It consists of dark green hornblende differing in colour and pleochroism from the hornblende of the vogesite, and turbid felspar, which is mostly alkali-felspar. A foliated structure is pretty obvious in the microscopic section, especially in the arrangement of the clustered, ill-shaped hornblende prisms. This hornblende-schist is an igneous rock; another hornblende-schist has a pale green hornblende and looks to be a sedimentary schist. It possibly represents the 'green beds' that have been described by Mr. Cunningham Craig.

One curious inclusion has a spotted character owing to the presence of many rounded felspar grains. These are surrounded by brown biotite plates in a matrix of felspar. This rock is evidently intensely contact altered. In some respects it has a resemblance to the albite-gneisses but the felspar which is for the most part alkali-felspar has negative optical sign while albite is positive.

The most interesting inclusions, however, are those which contain a pink garnet that seems to be almandine (alumina-iron garnet). In many of these the garnet is visible to the unaided eye. These rocks are all highly schistose, even though many of them are intensely contact altered; they are in no respect hornfelses. They are often much decomposed and contain biotite and chlorite with abundant felspar. The chlorite is clearly secondary but the biotite seems often due to contact alteration. Muscovite is not present; presumably it has been altered to felspar. In addition to garnet they mostly contain brown staurolite, which seems to be a primary mineral of the schist. On the other hand the occasional presence of sillimanite, cordierite and corundum is to be ascribed to contact alteration. Neither kyanite nor andalusite has been observed in any of these rocks but both might reasonably be expected to be present if a larger collection of specimens had been made.

The garnet crystals are in nearly all cases intensely corroded. Wherever they have been touched by the magma they are surrounded by a dark zone which consists of chlorite with magnetite. In places the dark magnetite grains have transparent greenish borders so that they belong partly to spinel. Often the smaller garnets are entirely replaced by pseudomorphs of this nature, of which the origin is indicated only by the rounded shape. In other cases a core of garnet remains, sometimes of very irregular outline. Some crystals look as if they had been melted, and dendritic crystallitic growths appear in them; around others there is a narrow zone that looks like brown glass. The melting of almandine enclosed in volcanic rocks is well known and has been described and figured by Brauns.[1] It seems, however, a little difficult to believe that glass

[1] Brauns, R., 'Die chemische Zusammensetzung granatführender kristalliner Schiefer, Cordieritgesteine und Sanidinite aus dem Laacher Seegebiet,' *Neues. Jahrbuch f. Min.*, B.-B. xxxiv, 1912, p. 85. Pl. v.

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would appear in a well crystallized rock like this lamprophyre, but Mr. H. G. Smith has recently shown me quartz inclusions in a minette from near Sedbergh that are undoubtedly surrounded and penetrated by films of brownish glass.

It is unfortunate that the decomposition of these inclusions is so general that it is impossible to be certain as to the original mineral or minerals represented by the chlorite enveloping the garnet residues. Comparative studies have shown that inclusions of almandine in igneous rocks may yield biotite, cordierite, hypersthene, augite, and even in some cases corundum. Probably much depends on the nature of the magma that attacked them.

The staurolite shows the same phenomena as the garnet except that it does not yield compact masses of chlorite. The characteristic outlines of the crystals are mostly preserved and in the interior there is generally an unchanged residue of irregular shape showing the colour, pleochroism and other optical properties of typical staurolite. Around this there is a dark zone consisting of magnetite and green spinel in densely crowded, perfectly formed little octahedral crystals.[1] Brauns has reported the production of corundum from staurolite[2] but this has not been seen in the Inverbeg rock though corundum occurs in some of the intrusions.

Around the corroded staurolites there is generally a clear zone, so that they form the centres of rounded white spots. In polarised light these spots prove to be clusters of rather large crystals of alkali (?) felspar. In fact the staurolites are giving place to aggregates of felspar and spinel, a process which indicates interfusion with the magma. Around the smaller garnets a similar zone can also be traced, though by no means so conspicuous. Brauns has described ejected fragments of garnet and staurolite schist in the Eifel tuffs that have been converted into sanidinites through the influence of hot gases from the magma. Their garnets and staurolites show exactly the same changes as we have described above. It should be noted that in a few instances small garnets and staurolites are seen that have not suffered any corrosion or alteration, but such crystals are entirely surrounded by the schist and seem to have escaped attack by the magma owing to this protection.

The garnetiferous and staurolite-bearing inclusions all show intense contact alteration. Some are completely recrystallized into masses that consist mainly of felspar and biotite; others still have their original schistose character fairly well preserved. Of the special minerals developed in them we may mention (1) sillimanite, in very typical needles and brushes, in one slide only (12912); (2) corundum, a few small grains of bluish colour in the

[1] Brauns, R., 'Die kristallinen Schiefer des Laacher Seegebietes und ihre Umbildung zu Sanidinit,' Stuttgart, 1911, Pl. 5, fig. 3; and Smith, H. G., 'The Lurgecombe Mill Lamprophyre and its Inclusions,' *Quart. Journ. Geol. Soc.*, vol. lxxii, 1916, p. 81; Koch, Max, 'Die Kersantite des Unterharzes,' *Jahrb. d. K. Preuss. Geol. Landesanst.* 1886, p. 44.

[2] Brauns, R., *Ibid.*, Pl. 5, fig. 4.

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same slide; (3) cordierite, rather doubtful in most cases and probably decomposed but almost certainly present in one slide.

From the above evidence it seems a fair inference that the lamprophyre of Inverbeg contains inclusions of several types of foliated metamorphic rocks. It is not possible to refer these specimens exactly and without ambiguity to their original sources. The intense contact alteration which they have undergone has changed their characters to a considerable extent. Yet it seems quite clear that many of them are much more metamorphic than the schists and sheared grits of the Ben Ledi series which are the country rocks at Inverbeg. As these inclusions must have been carried up from below, probably from depths of several thousand feet, by the rise of the magma, we are at liberty to conclude that garnetiferous and staurolitic schists underlie the Ben Ledi series near the south end of Loch Lomond.

As we pass northward from Inverbeg along the shores of Loch Lomond there is a steady increase of metamorphism. Albite-gneisses, hornblende-schists, and other highly foliated rocks are prevailing types. Then come the 'Green Beds' (sedimentary gneisses containing hornblende), the Loch Tay Limestone and the Garnetiferous Mica Schist.

From the Inverbeg lamprophyre I have obtained only one piece of limestone. It is dark grey, coarsely crystalline, evidently re-crystallized and contains small rhombic dodecahedra of yellow garnet. It is not possible to assert that it comes from the Loch Tay Limestone, though there seems no reason why that might not have been its source.

The only rock in the Loch Lomond basin that contains large almandine crystals is the Garnetiferous Mica Schist which is the rock that accompanies the Loch Tay Limestone on its northern side. That rock, however, has never been reported to contain staurolite. In other respects it is not unlike the garnetiferous inclusions in the Inverbeg lamprophyre.

When we search for the origin of the staurolite we are almost completely at a loss. It is not probable that this mineral was developed by the thermal action of the dyke, at great depths and under great pressure. It seems to be an original mineral of the schist. The same conclusion has been reached by Brauns with respect to the staurolite-schists of the Eifel. Now staurolite in the Southern Highlands of Scotland has a distribution that suggests that it is a contact mineral of the Older Igneous Intrusions. It was not found in Cowal by Clough and is not reported west of the Garry in Perthshire. In Aberdeenshire and Banffshire, however, it is very widespread and has been reported by Heddle, Hinxman, Barrow, Read and other geologists from many localities. It is very frequently, though not always, associated with masses of igneous gneiss or foliated granite. Becke[1] has shown that it may

[1] Becke, F., Tschermak's Min. Pet. Mitteil, vol. 34, 1917, p. 67.

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be developed by pressure at the expense of original cordierite. It is possible accordingly that deeply situated below Inverbeg there may be masses of Older Granite. This is not unreasonable but there is no other evidence of it. There is no Older Granite in Argyllshire or Stirlingshire; the nearest rocks of this type occur near Pitlochry, sixty miles to the north-east of Inverbeg.

These facts bring us to the consideration of one of the most obscure and debatable problems of Scottish Highland geology. It has generally been held by those who have mapped and described this ground that there is an ascending sequence from the Highland border northwards. From this statement we must exclude the narrow zone of border rocks which contain fossils of Cambrian age and are in many places faulted against the Highland schists that lie to the north of them, though the presence of a fault separating these two has not always been conceded. The Ben Ledi Series, however, has usually been regarded as underlying the Loch Tay Limestone and the Garnetiferous Mica Schist. Reference may be made to Cunningham Craig's descriptions of Loch Lomond-side, and to the memoir on Blair Atholl and Pitlochry (Sheet 55) and Mr. Barrow also has repeatedly stated that the sequence ascends from near the Highland border in a north-westward direction. I have not been able to find that Clough committed himself to this opinion in the Cowal memoir and recently Mr. Tilley had directed attention to some anomalies in the situation.[1] If it is true it is inconvenient for those who maintain that degree of metamorphism is dependent to a large extent on depth of situation, for the Loch Tay Series is far more highly metamorphic than the Ben Ledi Series, a fact universally admitted. I am well aware that there are difficulties to be faced, no matter which sequence we adopt. If the inclusions in the Inverbeg lamprophyre dyke are trustworthy indications of the nature of the underlying rocks it is difficult to avoid the conclusion that the Ben Ledi grits and schists rest upon a more metamorphic series that has the characters of the rocks that outcrop to the north of Inverbeg, and consequently that the sequence in this part of the Southern Highlands is an ascending one from north to south.

[1] Tilley, C. E., 'A Preliminary Survey of Metamorphic Zones in the Southern Highlands of Scotland,' *Quart. Journ. Geol. Soc.*, vol. lxxxi, 1925, p. 107.

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IV.—THE ZONAL SUCCESSION IN THE COAL MEASURES AROUND MANCHESTER

By W. B. Wright, Sc.D.

Plates I, II, III

INTRODUCTION

The Middle Coal Measures of Lancashire have a thickness of 5,500 feet from the Arley Mine to the base of the Ardwick Series. Of these the upper 2,000 feet are very little known, but as *Anthracomya phillipsi* occurs at their base it is to be presumed that they belong to this zone. In Lancashire the highest known Carbonicolas, probably impoverished representatives of the long range form *C. aquilina*, occur 200 feet below the Dukinfield Marine Band, but a fauna of Anthracomyas quite distinct from the *phillipsi* group is found below the Worsley Four Foot Mine, that is to say in a position presumably stratigraphically higher than the above-mentioned marine band. Above the Worsley Four Foot *A. phillipsi* and its variants are the only known Anthracomyas.

The better known strata from the Arley to the Worsley Four Foot are capable of a broad zonal subdivision comparable with that described by Clift and Trueman for Nottinghamshire and Derbyshire,[1] and by Hopkins[2] for Durham and Northumberland, that is to say the Ovalis, Modiolaris and Pulchra Zones are separable but the Similis Zone of S. Wales[3] cannot be traced. Further subdivisions of the zones can also be effected on a faunal basis, but it is not yet known to what extent these subzones are traceable laterally, though some of them certainly hold for considerable distances within the coalfield itself.

In the 3,300 feet of strata between the Arley Mine and the base of the Phillipsi Zone at the Worsley Four Foot, it so happens that there is a natural triple subdivision, punctuated by two groups of thick workable seams, the Trencherbone Group and the Roger Group. It is not without significance that these coal groups limit the faunal zones, the Trencherbone Group occurring between the Ovalis and Modiolaris Zones, and the Roger Group between the Modiolaris and Pulchra Zones. Only long range forms transgress the vertical limits set by these coal-groups, and even these may on further study prove capable of subdivision.

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[1] Clift, S. C., and A. E. Trueman, 'The Sequence of Non-Marine Lamellibranchs in the Coal Measures of Nottinghamshire and Derbyshire,' *Quart. Journ. Geol. Soc.*, vol. lxxxv, 1929, p. 77.

[2] Hopkins, W., 'The Distribution of the Mussel Bands of the Northumberland and Durham Coalfield,' *Proc. Univ. Durham Phil. Soc.*, vol. viii, 1928, part 1.

[3] Davies, J. H., and A. E. Trueman, 'A Revision of the Non-Marine Lamellibranchs of the Coal Measures, and a Discussion of their Zonal Sequence,' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 210.

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In the description of the fauna every endeavour has naturally been made to use the existing nomenclature, but the imperfection of many of the type specimens, the complete loss of others, combined with extremely inadequate descriptions and figuring, make it impossible to get far without establishing new species. It is probable that more of the existing names could have been used if accurate localities and horizons had been cited, because it might then have been possible to obtain topotypes and to re-establish the species on a firm foundation. The localities are, however, extremely vague, generally consisting of the name of a town such as Wakefield, and the horizon is usually given as Coal Measures. The material dealt with by Wheelton Hind[1] is in a better state as regards definition of locality and horizon, but he originated very few new species and gave such a wide interpretation to old ones that it is in most instances futile to continue in his use of the nomenclature. The species described in 1927 by Davies and Trueman[2] from the coalfields of South Wales are accurately horizoned, and, the types being accessible, it is possible to identify a number of them as present in the Lancashire coalfield and others as represented by closely related forms. Davies and Trueman have, however, been very economical in the creation of new species, and there is moreover considerable difference in the known faunas of these two fields. It has therefore become expedient to publish descriptions of a number of types.

Description of Species

Carbonicola boltoni sp. nov.

Plate I, figs. 5, 5A, 5B, 6, 7.

1897. *Tellinomya robusta* H. Bolton. *Mem. Manch. Lit. Phil. Soc.*, vol. xli, No. 6, p. 5, pl.v, figs. 6-8.

Holotypes in Manchester Museum, specimens L. 3492 and 3493, from Watergate Colliery, Middle Hulton, Lancs. Horizon, Middle Coal Measures, above the Cannel Mine.

Paratypes: 48648, He3990, He3997 B., Geological Survey Collection, from above the Cannel or King Mine, Peelwood Colliery, Tyldesley, Lancashire.

As pointed out by Jackson[3] in 1912, these shells are preserved only as casts and appear to be Carbonicolas. The full rounded form of the umbones and their contiguity seem, however, to indicate that the shell was thin. The casts therefore gave a fair idea of the form of the shell. There is much variation in form within the bed, but this may be largely ascribed to distortion by crushing. The truncated

[1] Hind, Wheelton, 'A Monograph on Carbonicola, Anthracomya and Naiadites,' *Palaeontographical Society*, 1894-96.

[2] *Op. cit.*

[3] Jackson, J. W., 'Palaeontological Notes from the Manchester Museum: On Mollusca from the Lancashire Coal Measures,' *Geol. Mag.*, 1912, p. 449.

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appearance of Bolton's types, L.3492-3, is possibly due to the same cause, but the true outline of the lateral view of the shell is probably given by the right valve of L.3493.

Description.—The umbones are full and rounded, and circular or broad oval in horizontal section. The dorsal slope is strongly to gently curved, and sweeps continuously into the ventral margin through a rounded angle of about 60°. The ventral margin is strongly and almost uniformly curved, the point of maximum curvature varying somewhat. It sweeps upward from a point beneath the umbo into the well-rounded and occasionally prominent anterior end, which in its turn meets the slightly re-entrant frontal umbonal slope in a well-rounded obtuse angle.

The shell is extremely broad and stout. The lunule is broad and well marked, both it and the frontal aspect of the shell being gracefully heart-shaped. The maximum width is behind the umbones, about the middle of the length of the shell, and at one-third or less of the height from the umbones. The paratypes are better preserved than the holotypes and should be consulted. They show on the dorsal or posterior umbonal slope a vaguely defined spindle-shaped or elongated heart-shaped area somewhat like the lunule in outline. This may possibly be the escutcheon referred to by Bolton. It is feebly and partially seen on L.3492. A groove extending half-way down the centre of it contains the ligament.

Dimensions* of holotype, L.3493 :—l=32 h=75 t=64 a=37·5
,, paratype, 48648 :—l=28 h=86 t=57 a=32

These specimens are both slightly distorted, a fact which may partly account for the divergence in the measurements; the paratype is probably nearer the true shape.

Range.—This shell is, as far as is known, confined to a limited area of the Cannel Mine in the western part of the Lancashire Coalfield. It is not known in the eastern or Oldham area, in a portion of which, at any rate, sandy strata occur over the equivalent Black Mine.

Carbonicola os-lancis sp. nov.

Plate II, figs. 5, 5A, 5B, 6.

Holotype: 48651. Paratypes: (1), He3030; (2), 48643. All in the Geological Survey Collections.

Description.—A fairly elongate shell, 3–4 cm. in length, characterised by the obliquity of its truncation, which gives to the posterior

* Length (l) absolute in mm.; height (h), width (t), and anterior end (a), as percentages of length.

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end of the shell a bevelled or chisel-like appearance when viewed from the side. The umbones have little prominence and are probably long-ovate in section. The postero-dorsal slope is gently curved and abruptly cut off at an angle of about 140° by the posterior truncation. This is also gently curved and makes with the ventral border a slightly rounded angle of about 60 or 70°. The ventral border is very gently curved or nearly straight at the posterior end, but becomes more curved as it passes forward. The point at which the upward sweep into the frontal lobe begins seems variable in position, and the maximum depth may be behind, under or even in front of the umbo. The frontal lobe is well-rounded and in the types sweeps into the anterior umbonal slope without angulation. The anterior umbonal slope is short and hardly at all re-entrant.

The width of the shell is not accurately known, but cannot have been great. The maximum width is apparently under the umbones, and one-quarter to one-third of the distance from the umbones to the ventral margin.

The shell in most specimens has disappeared, but paratype (1) has sufficient preserved to show that it was thin, and its loss does not seriously affect the form.

Dimensions of holotype : l=30 h=52 t=20 ? a=27
,, paratype (1) : l=29 h=50 t=? a=27
,, ,, (2) : l=42 h=48 t=22 ? a=24

Resemblances.—This shell may be a variant of *C. subconstricta* (J. Sow.), as lectotype of which we take the original of Hind's pl. vii, fig. 6, 1895, regarding fig. 5 as a different form, possibly allied to *C. communis* Davies and Trueman. In *C. os-lancis* the umbo is much less prominent, and the posterior truncation more oblique.

There is some possibility of confusion with *C. venusta* Davies and Trueman, and shells having affinity with the latter occur on the same horizon. The frontal lobe in *C. os-lancis* is rounder and higher, the anterior umbonal slope is shorter and less re-entrant and the posterior truncation is generally more oblique and shorter.

Localities and horizon.—Holotype : Astley Green Colliery, S.E. of Tyldesley, Lancashire. One-inch map 85, six-inch map 102 N.E., from above the Trencherbone Mine, Middle Coal Measures.

Paratype (1) : Lowside Brickworks, Glodwick, S.E. of Oldham, Lancashire. One-inch map 85, six-inch map 97 S.W. Midway between the Blenfire and Oldham Great Mines about 40 feet above the latter.

Paratype (2) : Same locality, about 25–30 feet above the Oldham Great Mine.

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Carbonicola os-lancis, var. *pectorata* var. nov.

Plate II, fig. 7.

Type: 48652, Astley Green Colliery, S.E. of Tyldesley, Lancashire. One-inch map 85, six-inch map 102 N.E., from above the Trencherbone Mine, Middle Coal Measures. In the Geological Survey Collection.

This differs from the more normal individuals of the species in having the frontal lobe much fuller and more rounded so that the greatest depth of the shell tends to be slightly in front of the umbones. The ventral margin is straight or slightly re-entrant towards the posterior end. The relation to the normal type is much the same as that of *C. robusta* Hind (*non* Sow.) to *C. acuta* or *C. subconstricta*.

A closely allied variant exemplified by specimen He4085 in the Geological Survey Collection is almost identical in form with *C. similis* (Brown).

Dimensions of type: l=43 h=53 t=16? a=28

C. elliptica sp. nov.

Plate II, figs. 2, 2A, 2B, 3.

Holotype: 48640, from horizon M.C. 1A 340 feet above the Oldham Great Mine in Moston Colliery, Manchester.

Paratypes: 48639, LT.429, 435, from same locality and bed; LT.361 and 366, horizon M.C. 1, just below M.C. 1A in same locality. All types in the Geological Survey Collection.

Description.—Shell 2 to 2½ cm. in length, of deep oval outline and displaying a variable degree of posterior truncation. Umbones not prominent, umbonal sections probably oval. Dorsal slope very slightly curved, variably passing into or cut off by the posterior margin or truncation at an angle of about 130°. The posterior margin sweeps evenly without noticeable angulation into the well curved ventral margin, and the latter passes equally indefinitely into the well rounded ventral lobe. In solid specimens the frontal margin is cut off at an obtuse angle by the slightly re-entrant frontal umbonal slope, but with progressive crushing this angle and the re-entrant curve of the frontal umbonal slope become obliterated, giving to flattened specimens the appearance of a full and high frontal lobe.

The shell is slightly and evenly tumid, the maximum width being a little behind the umbones and a little more than a third of the depth of the shell below them. The shell substance is not preserved in any of the specimens, but it was probably thin, with delicate lines of growth. These show that the slight posterior truncation tends to increase with maturity.

Dimensions of holotype: l=21 h=71 t=38? a=36.

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Resemblances.—This shell bears a certain resemblance to *C. similis* (Brown), but, if the figure of this properly represents the type, there is not likely to be any confusion, Brown's species having a short posterior truncation and a well-marked posterior-inferior angle.

Horizon and Range.—These and closely related forms occur in great abundance in the lower part of the Modiolaris Zone. They do not appear to range into the upper part of the zone, and are completely absent in the Ovalis Zone below.

Carbonicola cycloquadrata sp. nov.

Plate II, fig. 8.

Type: 48638, from horizon M.C.1, 340 feet above the Oldham Great Mine in Moston Colliery, Manchester. Geological Survey Collection.

Description.—A shell of rounded quadrate form a little over 2 cm. in length, with prominent nearly central umbones. The postero-dorsal slope is straight and short, being abruptly truncated at an angle of about 130° by the long posterior margin, which is gently curved and sweeps through a rounded angle of about 70° into the ventral margin. The latter is gently curved and sweeps upward from a point below the umbo into the blunt and vertically elongated anterior lobe, which is cut off at a level distinctly below the umbo by the slightly re-entrant anterior umbonal slope. Owing to the vertical elongation of the anterior lobe there is a distinct, nearly straight or gently curved frontal margin, which makes a very rounded angle of about 100° with the ventral margin.

Shell with slight and even tumidity, the greatest width being a little behind the umbo and about one-third of the height from it. The shell substance is not preserved on the type but was probably thin. The existing surface is faintly marked with delicate lines of growth, which, except very near the umbo, follow the outline of the shell and show that it took on its characteristic cyclo-quadrate form at an early stage.

Dimensions of type: l=21 h=83 t=38? a=36.

Affinity.—This species is obviously related to *C. dawsoni* (Brown) which occurs about 50 feet higher in the succession. It has somewhat less central umbones and differs completely in contour.

Range.—*C. dawsoni* and *C. cycloquadrata* may be taken as representatives of a group of forms in which the shell approaches circularity, with more central umbones and greater depth than is usual. They are never common, and hitherto have been found only in the lower part of the Modiolaris Zone, in the metals above and below the horizon of the Doe Mine.

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Carbonicola carissima sp. nov.

Plate I, fig. 9, 9A.

Holotype: 48644, from stream sections south of Oaken Bottom Mills, Tonge Fold, south-east of Bolton. One-inch map 85, six-inch map 87 S.W. Just below the Peel Hall Rock.

Metatypes: He2900 and 2902-7, same locality. Paratypes LT.854-858 and 860 from horizon M.C.5. Moston Colliery, Manchester. Just below the Huncliffe Rock. All types in the Geological Survey Collection.

Description.—A small shell about 1 cm. in length. The postero-dorsal slope is gently curved, the greater depth of the shell being a little behind the umbones, sometimes even well behind them, so that the shell becomes in outline almost like an *Anthracomya*. Posterior end definitely truncated, the gently curved truncation making an angle of about 120° with the postero-dorsal slope. The rounded postero-ventral angle is difficult to measure on account of the curving of the truncation: it is about 90° or may be less. The ventral margin is straight or rarely very gently curved. It sweeps up into the frontal lobe from a point under or a little behind the umbones. The frontal lobe is well rounded in outline in its lower portion, but tends to be cut off at an angle somewhat below the level of the umbones, where the surface recedes into the lunule, the anterior umbonal slope being fairly long, re-entrant and well marked in proportion to the size of the shell, but variable. The lines of growth are well defined, sometimes even coarse, and tend to be tilted forward a little near the umbo.

Dimensions of holotype: l=11 h=52 t=45? a=21.

,, paratype (LT.854): l=13 h=55 t=35? a=28

Resemblances.—These small shells approximate to others slightly larger approaching *C. concinna* and *C. aquilina*, which occur on the same horizon. It is conceivable that they are young of these, but they keep fairly well to one size and are abundant and apparently characteristic of one horizon on both sides of the coalfield. The most *Anthracomya*-like forms of this species show an approach to those forms of *A. pulchra* (from below the Roger) which have no marked posterior expansion. There is a certain resemblance to *C. angulata* Hind from the Low Bottom Bed of Burnley, but the marked angulation of the carina characteristic of the latter is absent.

Range.—So far as known, this appears to be confined to two beds within 100 feet vertically of one another. It is useful in that it gives a correlation across the field.

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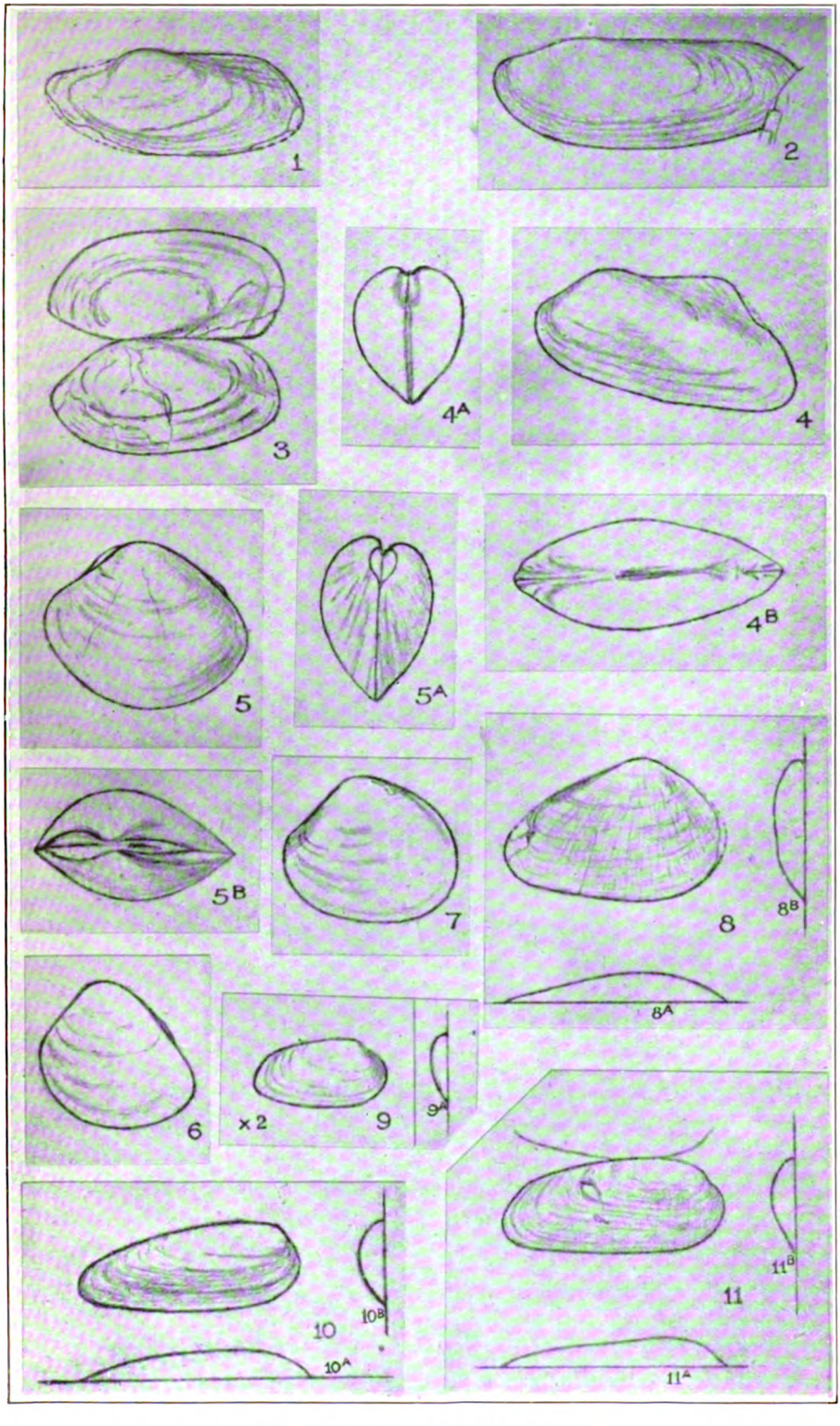

ANTHRACOMYA AND CARBONICOLA

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Carbonicola retrotracta sp. nov.

Plate II, figs. 1, 1A, 1B.

Holotype : 48642, from the right bank of the River Tonge, south of Mill Hill Bleach Works, Tonge Moor Road, Bolton. One-inch map 85, six-inch map 87 S.W. Below the Lower Yard Mine. Paratype : He2923, from the stream section west of Oaken Bottom Mills, Tonge Fold, south-east of Bolton, apparently above the Lower Yard Mine, but the seam is not visible. All types in the Geological Survey Collection.

Description.—A rather large coarse shell generally about 4 or 5 cm. in length, the outstanding character of which is the great postero-ventral elongation. This leads to marked tilting of the umbones and early lines of growth, which may thus come to make an angle of 30° with the ventral margin of the mature shell.

Umbones as far as can be seen not noticeably prominent. Umbonal sections very elongate. Postero-dorsal slope curved, the greatest depth of the shell being a little behind the umbones. Posterior end definitely, though somewhat roundly, truncated at an angle of about 130° with the postero-dorsal slope. The rounded posterior inferior angle is about 80 or 90°. The ventral margin is nearly straight in its posterior portion, but sweeps upward from a point a little behind the umbones into the rounded anterior lobe, which is moderately high. Shell moderately and evenly tumid, the tumidity having a large vertical extension from near the umbones to about one-third of the height from the ventral margin.

Dimensions of holotype : l=48 h=50 t=29 a=22

,, paratype : l=55 h=61 t=? a=18 ?

Resemblances.—This shell resembles in outline some forms of *C. rhomboidalis* as figured by Wheelton Hind, but not the lectotype as chosen by Davies and Trueman. It is, however, distinguishable by the much more extreme postero-ventral elongation and consequent tilting of the umbones and lines of growth. The posterior truncation is also more marked. It is very near *C. aquilina* (J. de C. Sow.), of which it is most likely a variant, but is larger and more produced postero-ventrally, with greater tilting of the lines of growth. It is also near *C. phrygiana* sp. nov., but has the postero-dorsal slope less arched and the inferior margin in general less curved.

Range.—So far as known, this is confined to the beds above and below the Lower Yard Mine of Bolton, and the equivalent Pemberton Five Foot Mine of Cleworth Hall Colliery. It has not been found in the east of the coalfield.

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Carbonicola phrygiana sp. nov.

Plate II, figs. 4, 4A, 4B.

Type in Manchester Museum, E. collection, Wild, W.551, from the Stubbs Mine, Bardsley, Lancashire.

Description.—Umbones prominent, not much, if at all, raised above the hinge line, but tilted forward over the lunule. Dorsal slope notably curved or arched, often rising above the level of the umbones, and sweeping without posterior truncation into the lower border. This border is fairly straight in the posterior half of its length, but sweeps upward from a point well behind the umbones and generally about the middle of the shell into the rounded but rather short anterior lobe. Anterior umbonal slope short but deeply re-entrant. From the margin inward the lines of growth are tilted progressively until, as they approach the umbo, they make a very considerable angle (in the holotype about 40°) with the straighter portion of the lower border.

The shell retains a fairly even width for a considerable part of its length, the maximum width being situated at about a third of the height from the umbo. The umbonal sections are elongated and in the type the umbones are eroded.

Dimensions of holotype: l=43 h=56 t=36 a=15?

Resemblances.—An obvious variant of *C. aquilina* (J. de C. Sow.), from which, however, it differs completely in outline. It has points of resemblance to *C. retrotracta* sp. nov., into which it seems to pass by a series of intermediate forms on the horizon of the latter. The back is more arched than in *C. retrotracta* and sweeps without truncation into the ventral margin. It is also closely related to *C. sulcata* (Brown), but differs markedly in the tilting of the lines of growth, if these are correctly represented in Brown's[1] figure.

Range.—*C. phrygiana* and its allies, all characterised by a strongly arched dorsal slope and highly tilted umbones and lines of growth, appear to be confined to the Modiolaris Zone, having thus a more restricted range than *C. aquilina*.

Carbonicola concinna sp. nov.

Plate I, fig. 11, 11A, 11B.

Holotype: 48645, from above the Ashclough Mine, immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E. In the Geological Survey Collection.

[1] Brown, Capt. Thomas, 'Fossil Conchology of Great Britain and Ireland,' London, 1849, pl. lxxiii, fig. 29.

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An elongated shell of medium to small size attaining a length of 3 cm., but often less. The umbones have very little prominence and the maximum height of the shell may be slightly behind them. The dorsal slope is very gently curved, but does not sweep continuously to the postero-ventral angle, being definitely truncated at an angle of about 140°, the postero-dorsal angle thus formed being slightly rounded off. The height of the shell at its truncation is about two-thirds of its maximum height, so that the dorsal and ventral margins of the shell are slightly convergent. The rounded postero-ventral angle is about 65°. The ventral margin is straight, but begins to sweep upward into the frontal lobe at a point a little behind the umbo. The anterior lobe is short, rounded and high, the anterior umbonal slope being short and only slightly re-entrant. The shell is not very tumid, the maximum width being situated about one-third or more of the height of the shell beneath the umbones, and having a considerable extension backwards from this point along the length of the shell. The umbonal sections are elongate. The surface is marked with faint growth lines not strongly tilted.

Dimensions of type : l=31 h=42 t=22·5 ? a=14·5

Resemblances.—This species is near *C. nitida* Davies and Trueman, but distinguishable by the shorter, more rounded, and higher anterior lobe and slightly curved dorsal slope.

It is also near *C. acutella* sp. nov., but is distinguishable by the marked posterior truncation.

It is also near *C. aquilina* (J. de C. Sow.), of which it is probably a development, but is distinguishable by the shorter, more rounded and higher anterior lobe and the less tilted lines of growth.

Range.—*C. concinna* enters about the middle of the Modiolaris Zone and ranges up into the middle of the Pulchra Zone. The type comes from the top of its range.

Carbonicola acutella sp. nov.

Plate I, fig. 10, 10A, 10B.

Holotype : 48647, from above the Ashclough Mine immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E.

Paratypes : He2987 and 2982, from the same locality. All types are in the Geological Survey Collection.

Description.—An elongated shell of comparatively small size, attaining a length of over three centimetres but often two or less. The umbones have very little prominence, the greatest depth of the shell being often posterior to them. The dorsal slope is gently curved, the curvature extending to the pointed posterior end which shows little or no truncation. The ventral margin is nearly straight

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in its posterior portion, the straightness continuing for two-thirds of the length, but curves gently upwards into the rounded anterior lobe. The anterior lobe is short and high, the anterior umbonal slope being short and only slightly re-entrant. The surface is marked with faint lines of growth, not noticeably tilted except possibly near the umbo, where they are usually obscure. The shell is evenly tumid, the position of maximum thickness being situated a little behind the umbones but having a considerable extension backwards from this point along the length of the shell. It is slightly nearer to the umbo than to the ventral margin.

Dimensions of holotype: l=32 h=37·5 t=28 a=11·5

Resemblances.—Wheelton Hind figures no species with which this can be compared. He would no doubt have regarded it as a variant of *C. aquilina*. Brown figures nothing resembling it, nor do Davies and Trueman.

It may be closely allied to *C. concinna* sp. nov., but is distinguished by the absence of a posterior truncation.

Range.—Horizon B.C.7, Bradford Colliery, Manchester, 100 feet above the Bradford Top Mine, and horizon M.C.12 of Moston Colliery, Manchester, are without question identical one with the other, and with the bed above the Ashclough Mine from which the type material is derived. They yield *C. acutella* in abundance. Identical or closely related forms are found in Bradford Colliery on horizons B.C.6 and B.C.5, approximately 100 and 150 feet above the type horizon; they are, however, not common and are doubtfully if at all represented at the same levels at Moston Colliery. Allied forms also occur fairly commonly some 400 feet below the type horizon in the well known shell beds between the Top Furnace and Roger Mines of Oldham (M.C. 7 and 8). They have not been proved in any intermediate beds. The shell thus ranges throughout the greater part of the Pulchra Zone and is confined to it.

Carbonicola radiata sp. nov.

Plate I, fig. 8, 8A, 8B.

Holotype: 48641. Paratypes: LT. 1470 and 1464, all from the return airway in Bradford Colliery, Manchester, horizon B.C.7, 100 feet above the Bradford Top Mine. Geological Survey Collection.

Description.—A robust shell of ordinary elongation, generally about 3 cm. in length. Umbones fairly prominent. Umbonal sections ovate. Dorsal slope gently curved and making an angle of about 40° with the posterior half of the ventral margin, into which it sweeps gradually with little or no truncation. Ventral margin curved throughout, but less so posteriorly and sweeping up from a

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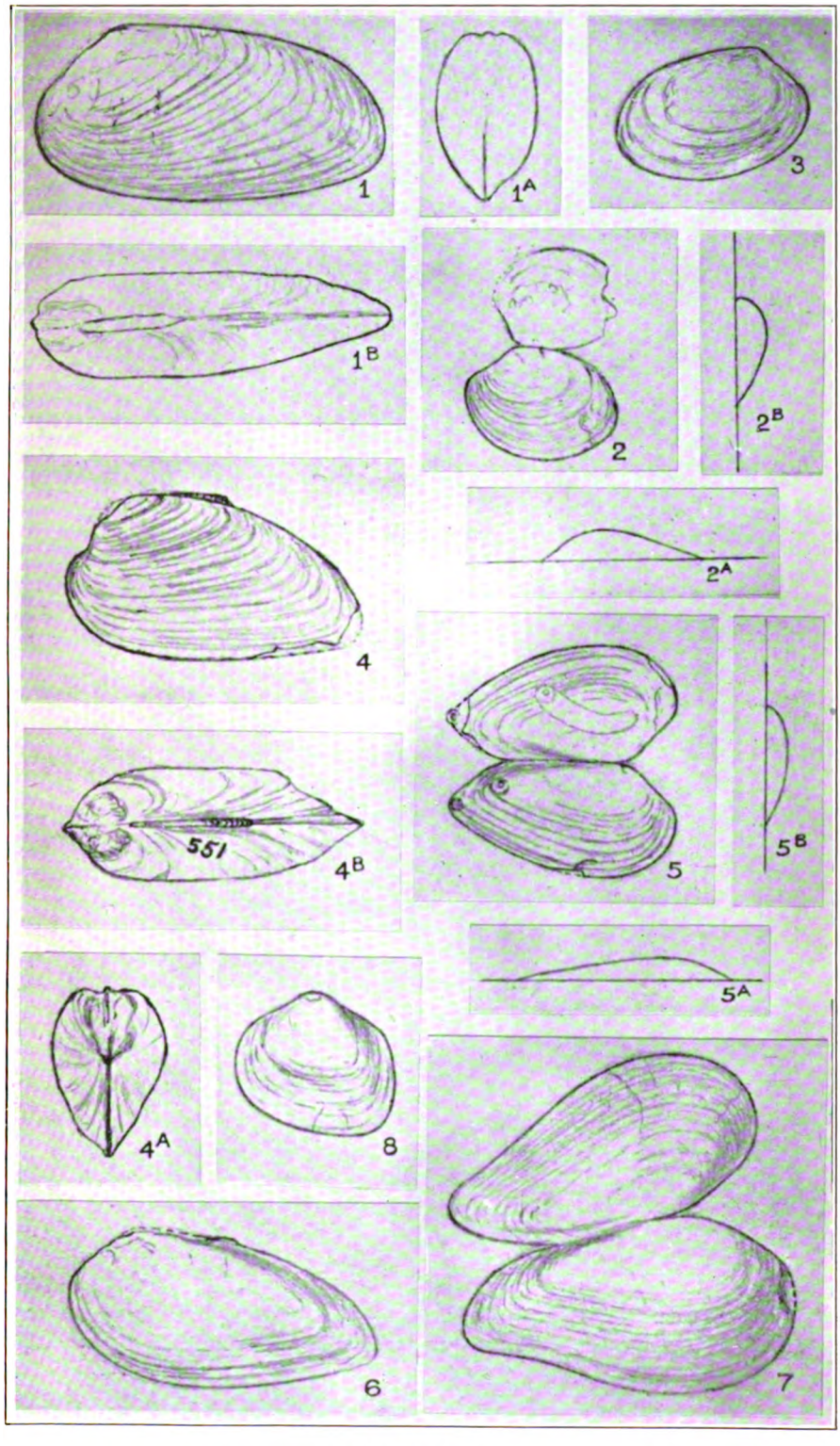

CARBONICOLA

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point beneath or behind the umbo into the rounded and fairly high anterior lobe. Anterior umbonal slope of moderate length and only slightly re-entrant.

Shell not very tumid, the maximum width being situated beneath the umbones and more than one-third of the height of the shell from them. The shell substance is thick and apparently consists of two layers of calcite. When the outer is stripped off the inner is seen to be distinctly striated in a radial direction. This striation is sometimes rather feebly displayed on the inner and outer surfaces. The lines of growth appear to maintain their parallelism with the ventral border almost if not quite into the umbones.

Resemblances.—*Carbonicola obtusa* Hind (1895, pl. vii, fig. 16) from the Lower Coal Measures of N. Staffordshire, is fairly comparable with *C. radiata* in general form, but there is no sign of radial striation in Hind's species.

Range.—As far as is known this species is confined to a single horizon. It is found again at this same horizon (M.C.12) in Moston Colliery, Manchester, and occurs also in the bed above the Ashclough Mine in the Bolton Area, and again at 330 feet in Moston Mill Borehole.

Anthracomya fisheri sp. nov.

Plate I, fig. 4, 4A, 4B.

Type: 48653. From above the Doe Mine, Pendleton Colliery, Lancashire, in the collection of the Geological Survey. Presented by Mr. F. H. Fisher, Manager of Bradford Colliery, Manchester.

Description.—A tumid shell with the maximum depth definitely at the posterior end. Umbones swollen and rising somewhat above the hinge line. Hinge line about half to three-fifths of the total length of the shell, fairly sharply cut off at an angle of 120–130° by the posterior margin. The latter is straight or slightly curved, passing with a rounded angle of 40 or 50° into the almost straight ventral margin, which is inclined to the hinge line at an angle of about 15° but sweeps upward from a point below the umbones into the rounded frontal lobe. The frontal margin passes without noticeable angulation into the almost straight frontal umbonal slope at a level slightly below the hinge line.

A well marked broadly swollen carina passes from the umbones obliquely backwards, bowing slightly forwards as it passes on to the sides of the shell and thence again backwards to reach the margin of the shell at the postero-ventral angle, losing definiteness as it goes. The greatest thickness is well behind the umbones a little in advance of the middle of the shell and about one-third of the total height from the umbones.

In front of the carina there is a slight constriction which broadens out and disappears before it reaches the straight ventral margin.

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Dimensions of type[1]: l=37 h=50 t=40·5 a=24 u=81 α=30–35° β=120–130°

Resemblances.—This species is near *A. insignis* Davies and Trueman, but is distinguished readily by the course of the carina, which does not reach the ventral margin in advance of the posterior inferior angle. This latter angle is also more acute than in *A. insignis*.

The straightness of the lower border and the acuteness of the posterior inferior angle separate this species from *A. robertsoni* (Brown).

The specimen figured by Hind, 1895, pl. xvi, fig. 53, from the Grains Ironstone, Dudley, South Staffordshire, is very near *A. fisheri*, and specimen LT.537 (Geological Survey Collection) from horizon M.C.2B, Moston Colliery, Manchester, 400 feet above the Oldham Great Mine, shows an approach to this species, but has a longer hinge line and a less acute posterior inferior angle. The latter character is, however, intensified in appearance if not entirely produced by crushing.

Anthracomya oblonga sp. nov.

Plate I, fig. 2.

Type: 48637, from horizon M.C.11 about 200 feet above the Roger Mine in Moston Colliery, Manchester. In the Geological Survey Collection.

Description.—An elongated anthracomyaform shell with straight hinge-line, and the greatest depth just behind the umbones, a little more than one-third of the length of the shell from the anterior end. The growth lines of the very rounded posterior end make an angle of more than 150° with the hinge-line, so that there is practically no truncation. There is no postero-ventral angle, the posterior margin passing with nearly constant curvature into the more gently but evenly curved ventral margin. The latter sweeps upward in a steady curve from the point of maximum depth a little behind the umbones into the frontal lobe, the margin of which meets the very slightly re-entrant anterior umbonal slope in a fairly sharp angle not far below the level of the umbones. The umbones are inconspicuous and rise little if at all above the hinge-line. The postero-dorsal slope shows slight radial striation.

Dimensions of type: l=42 h=36 t=? a=24 u=91 α=10° or less β=150° or more

Resemblances.—This species is quite distinct from any hitherto described. It has up to the present only been obtained from horizon

[1] The letters l, h, t, a, have the same significance as in descriptions of *Carbonicola*; u is the ratio of the umbonal to the maximum depth expressed as a percentage, α is the angle between the hinge line and the line joining the umbo to the posterior-inferior angle, and β is the postero-dorsal angle.

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M.C.11, Moston Colliery, Manchester, about 200 feet above the Roger Mine. The maximum depth is further forward than in the other two members of the *librata* group.

Anthracomya librata sp. nov.

Plate I, fig. 3.

Holotype: 48646. Topotype: He2983, from above the Ashclough Mine immediately below the weir, on the south bank of the River Irwell, ½ mile S. of Little Lever, Lancashire. One-inch map 85, six-inch map 95 N.E.

Paratype A. (LT.1222) from horizon M.C.12, Moston Colliery, Manchester.

Paratype B. (LT.1491) from horizon B.C.7, Bradford Colliery, Manchester.

All types in the Geological Survey Collection.

Description.—Shell of anthracomyaform type with straight hinge-line. Umbones rounded and not prominent, a little less than one-third of the length of the shell from the anterior end. Posterior superior angle slightly rounded and having a value of about 110°. Truncation of posterior margin gently curved, meeting the well curved ventral margin in a rounded posterior inferior angle almost impossible to measure, but roughly about 80 or 90°. Maximum depth about the middle of the shell. Ventral margin well curved, sweeping upwards from a point well behind the umbones into the rounded, prominent, and fairly high anterior lobe, the upper margin of which is formed by the slightly re-entrant anterior umbonal slope. The known specimens are somewhat flattened on shale, so that the plan and elevation cannot yet be described. Carina slight, if any.

Dimension of type: l=32 h=50 t=? a=27 u=90 α=23° β=110°

,, topotype: l=34 h=50 t=? a=29 u=94

Resemblances.—This is the best established of a group of species including also *A. oblonga* sp. nov. and *A. cymbula* sp. nov., which appear for the first time in beds above the Roger Mine, that is to say in the lower part of the Pulchra Zone. These species agree in the possession of a well curved lower margin and in the forward displacement of the point of maximum depth in comparison with its position in species occupying a lower horizon. The only comparable figured specimens are the type of the extremely doubtful species *A. wardi* Etheridge (Hind, 1895, pl. xv, fig. 14), a second specimen of which has never been found, and that figured by Hind from the Burnwood Ironstone (1895, pl. xv, fig. 15), a thousand feet higher than *A. wardi* Etheridge. The maximum depth is further forward in *A. librata* than in either of these.

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Anthracomya cymbula sp. nov.
Plate I, fig. 1.

Type: 48636, from horizon M.C.12, about 340 ft. above the Roger Mine, Moston Colliery, Manchester. In Geological Survey Collection.

Description.—An elongated anthracomyaform shell with the maximum depth about two-thirds of the length of the shell from the anterior end. Umbones rounded, fairly prominent, rising slightly above the hinge-line. Posterior margin or truncation making a slightly rounded angle of about 130° with the hinge-line, and sweeping with a well rounded angle of 50–70° into the well curved ventral margin. The ventral margin sweeps upward from a point about the middle of the shell towards the acutely rounded and shallow anterior lobe, the upper margin of which lies well below the umbones, and hinge-line, the anterior umbonal slope being markedly re-entrant. There is little or no carina and the postero-dorsal slope is radially striated.

Dimensions of type: l=35 h=40 t=27? a=26? u=91 α=16° β=130°

Resemblances.—*A. cymbula* somewhat resembles and is possibly allied to *A. lanceolata* Hind. The posterior margin or truncation is however, longer, so that the postero-ventral angle is not so near the hinge-line and the angle α is 16° instead of 10°. The anterior lobe is probably also a little longer. This species has also been found in the equivalent horizon (B.C.7) in Bradford Colliery.

Faunal Succession

The Ovalis Zone

With the above additions to the existing nomenclature it is now possible to summarize briefly the main faunal variations within the Manchester succession. The Ovalis Zone extends from below the Arley to the Cannel Mine (=Black of Oldham). The narrow belt between the Cannel and Trencherbone is in doubt, as none of the forms characteristic of that zone and restricted to it, such as *Carbonicola ovalis* (Martin), *C. centralis* (J. de C. Sow.), *C. robusta*, Hind (*non* J. de C. Sow.), have been found above the Cannel. The upper limits of *C. communis* Dav. and Tru. and *C. subconstricta* (J. Sow.) are not yet exactly determined, but Carbonicolas allied to these forms occur in this belt and also above the Trencherbone. The remarkable shells described above as *Carbonicola boltoni* sp. nov. occur in the debatable horizon in the roof of the Cannel Mine. They are not found in the east of the coalfield and may be entirely local in their distribution. Miss Emily Dix, however,

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EAST

WEST

BOLTON & TYLDESLEY AREA

ARDWICK GROUP

A. phillipsi & A. tenuis

A. tenuis

TENUIS

0

500

A. phillipsi recorded

BRADFORD FOUR-FOOT

1000

A. phillipsi recorded

PHILLIPSI

Beds of Coal Measure type recorded but not accessible.

1500 FT.

A. phillipsi

WORSLEY FOUR-FOOT

PARKER

A. cf. pulchra & A. spp. (large)

DUKINFIELD MARINE BAND

C. cf. aquilina

BC3. No Anthracomyas

C. fulva, C. acutella, C. aquilina

BC7, MC12. A. cymbula, A. librata, C. radiata, C. concinna, C. acutella, C. aquilina — ASHCLOUGH

PULCHRA

MC11. A. oblonga, A. cf. pulchra

A. cf. rubida ?

A. cf. williamsoni, C. fulva

ROGER

Entry of A. pulchra

CRUMBOUKE

FURNACE

A. cf. pulchra — RAMS

BARDSLEY ROCK

STUBBS

A. modiolaris, A. aff. robertsoni
C. turgida, C. exigua, C. affinis, C. cf. fusca
C. concinna, C. aquilina, C. phrygiana

PEEL HALL ROCK

LOWER YARD

C. retrotracta

HUNCLIFFE ROCK

MC5 C. carissima, A. modiolaris, Entry of C. concinna

MC4 C. carissima, C. aff. nitida &c.

MODIOLARIS

MC2 & 2A
MC1 & 1A

A. modiolaris, A. insignis, A. curtata, A. fisheri, C. venusta
Small round and oval Carbonicolas, e.g. C. dawsoni, C. cycloquadrata, C. elliptica
Entry of C. aquilina

DOE

OLDHAM GREAT

C. rhomboidalis, C. aff. venusta, C. cf. subconstricta, C. cf. communis
C. os-lancis, A. aff. insignis, A. cf. austicei

TRENCHER BONE

BLACK

C. boltoni — CANNEL

No exposures on East of coalfield

C. ovalis, C. aff. centralis
C. subconstricta, C. communis
C. robusta, Hind, non Sow.

OVALIS

ARLEY

ARLEY

C. aff. acuta, C. subconstricta

DIAGRAM SHOWING THE ZONAL SUCCESSION IN THE COAL MEASURES AROUND MANCHESTER.

Eastern section to scale; Western not to scale.

Faunas are connected by broken lines to the beds in which they have been proved. Those proved on both sides of the coalfield are connected to both sections.

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figures a closely similar shell from the top of the Ovalis Zone in South Wales.[1]

THE MODIOLARIS ZONE

The Trencherbone (=Oldham Great Mine) very definitely marks the base of the Modiolaris Zone, being characterised by an invasion of Anthracomyas allied to this species, such as *A.* aff. *insignis* Dav. and Tru. and other forms at present undescribable owing to poorness of material. *A. modiolaris* itself appears a little higher, and, in the Doe Mine some 300 feet above the Trencherbone, the *modiolaris*-fauna attains its greatest strength with *A. modiolaris* (J. de C. Sow.), *A. curtata* (Brown), *A. insignis* Dav. and Tru., and *A. fisheri* sp. nov. *A. modiolaris* extends upwards to the Stubbs Mine, in the roof of which it is found accompanied by *A.* aff. *robertsoni* (Brown). Whether it reaches further up above the Rams and Furnace Mines into the base of the Pulchra Zone must at present remain in doubt. The well known bed between the Furnace and Roger Mines on the east of the coalfield which marks the entry of *A. pulchra*, yields also a small form, which there is some difficulty in separating from *A. modiolaris*, as that species is at present defined, but it is not typical *A. modiolaris*. I have shown this shell to Dr. Trueman and he is of opinion that it is more allied to the *pumila*-group, of which I have little knowledge. At any rate *A. modiolaris* does not appear to extend above the Roger Mine.

The Modiolaris Zone is equally well characterised by its Carbonicolas. Here *C. aquilina* appears for the first time, being the lowest *Carbonicola* in the succession with a notably straight lower border. With many variations in form it ranges up from the Doe Mine right through the Modiolaris Zone at least into the middle of the Pulchra Zone. One of its most marked variants, now separated off as *C. phrygiana*, characterises the middle and upper beds of the Modiolaris Zone. Extremely elongate forms of this species, comparable with *C. lateralis* (Brown) occur on the horizon of the Doe Mine and also in the roof of the Rams, some 600 feet higher. They probably have a long range.

The lower half of the Modiolaris Zone has in addition a number of small rounded oval forms such as *C. dawsoni* (Brown), *C. cyclo-quadrata* and *C. elliptica*. These and *C. venusta* Dav. and Tru. are especially characteristic of the beds about the horizon of the Doe Mine. Below the Peel Hall Rock in the western part of the field a remarkable form now named *C. retrotracta* has a limited range and appears to be confined to the metals in the neighbourhood of the Lower Yard Mine. It might be briefly described as a large and highly steatopygous form of *C. aquilina*. This form is absent in the east. Higher still in the upper third of the zone occur forms which

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and adjoining Areas,' *Proc. S. Wales Inst. of Engineers*, vol. xliv, 1928, p. 460.

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recall the fauna of the Peacock or Brass Vein of South Wales, including *C. turgida* (Brown), *C. exigua* Dav. and Tru., *C. affinis* Dav. and Tru., and *C. sp. nov.* cf. *fusca* Dav. and Tru. These forms are especially characteristic of the roof of the Stubbs Mine in the eastern part of the field, but elsewhere this eminently recognisable horizon is cut out by sandstone.

At the same level as *C. retrotracta* occurs a remarkable little shell of restricted range, described above as *C. carissima*, which, unlike those just mentioned, gives a means of correlation across the field, occurring in abundance in horizon M.C.5, 600 feet above the Oldham Great Mine in Moston Colliery, Manchester and also below the Peel Hall Rock in the west. There is some doubt as to whether this should be classed as a *Carbonicola* or an *Anthracomya*. This same bed shows the first appearance of *C. concinna*, a form possibly allied to *C. nitida* Dav. and Tru., and ranging from this level up to the Ashclough Mine in the middle of the Pulchra Zone.

THE PULCHRA ZONE

The entry of *Anthracomya pulchra* Hind occurs in a bed well known on the eastern side of the field as lying between the Furnace and Roger Mines, where this species occurs in great profusion along with *Carbonicola concinna, C. aquilina, C.* aff. *turgida* and *C. acutella*, this last species making its first doubtful appearance at this level. This fauna has up to the present been located only in the eastern half of the field, where, however, it forms a valuable index-horizon. A little higher, in beds extending from the Roger to the roof of the Ashclough Mine, a fauna of larger Anthracomyas makes its appearance. These are quite distinct from the forms of the Modiolaris Zone below, being characterized by a well curved lower margin and a more forward position of the maximum depth of the shell. Among these are *A. oblonga, A. librata* and *A. cymbula*. *A. librata* has been found on both sides of the field. *A.* aff. *pulchra* and *A.* aff. *pumila* extend up to about 200 feet above the Roger Mine, but no Anthracomyas except *A. minima* have been found in the next 600 feet of strata extending from the Ashclough Mine to the Dukinfield Marine Band.

The Ashclough Mine is an important horizon which can be identified in both the east and west of the field. The coal with which it is associated in the east has no name. The fauna is a varied one, and embraces *C. fulva, C. acutella*, and *C. radiata*, which, so far as known, is confined to the horizon, *C. concinna, C.* cf. *nana* (Brown), *C. aquilina, A. cymbula, A. librata, A. minima* and *Naiadites spp. nov.*

Above the Ashclough Mine horizon the fauna becomes greatly impoverished. Species of *Anthracomya*, with the exception of *A. minima*, are wanting, and the Carbonicolas are represented by *C. fulva* and *C. acutella*, with possible doubtful variants of *C. aquilina*. *C. fulva* extends to 320 feet below the Dukinfield Marine Band, and the only known *Carbonicola*-band above this level is some 120 feet

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higher and contains an impoverished fauna of unidentifiable Carbonicolas, possibly *C. aquilina*, with *A. minima*. The occurrence of a strongly winged *Naiadites* in horizon B.C.3, 320 feet below the Marine Band, may be of zonal importance, as it is unknown at any other level.

The *Naiadites* of the Coal Measures present a rather difficult problem. There is unquestionably a much greater variety of form than has hitherto been described, and the existing nomenclature is entirely inadequate. No significance has for instance been attached hitherto to the presence or absence of an ear or wing at the postero-dorsal angle. All figured species are without it except *N. quadrata*, but winged forms indistinguishable in general outline from *N. modiolaris*, *N. carinata*, etc., also occur. The wing is not generally present in the early stages of growth and may or may not develop at maturity. The presence of an extremely pronounced wing seems to be peculiar to the upper beds of the Pulchra Zone, the above-mentioned horizon B.C.3 in Bradford Colliery, Manchester, yielding a form very remarkable in this respect. The material available is too imperfect for the establishment of a species.

Another character not noted in any described form of *Naiadites* is the presence of a posterior angulation of the margin and growth lines midway between the dorsal and ventral angles. *Naiadites* with this character range from the Cannel Mine to below the Peel Hall Rock, and, as far as known, are thus limited to the Modiolaris Zone, with extension into the debatable ground between this and the Ovalis Zone.

The Dukinfield Marine band has only been seen on the eastern side of the Lancashire Coalfield, and no fossil bands for a distance of 2,000 feet above it are known in this district. Direct palaeontological correlation with the west therefore fails at this point. Starting with the identifiable Ashclough Mine as a basis, however, stratigraphical considerations make it apparent that the Parker Mine of Bradford Colliery, which is 200 feet above the marine band, is the Worsley Four Foot of the west. Below the Worsley Four Foot occurs a bed with large species of *Anthracomya*. Of these no determinable specimens have yet been obtained, but two of them recall in their general shape species figured by Wheelton Hind[1] from the Burnwood Ironstone above the Gin Mine Marine Band of North Staffordshire. This is probably the locality given by Hind as Prestolee, from which he figures under the name of *N. elongata* an unquestionable *Anthracomya* of *pulchra* type. *A. pulchra* therefore appears to recur in Lancashire at this horizon. The type material comes from the Burnwood Ironstone. The locality therefore is worthy of further investigation, since it affords an opportunity of testing on external evidence the supposed identity of the Dukinfield and Gin Mine Marine Bands. The evidence available at present favours this correlation.

[1] Hind, Wheelton, *op. cit.*, 1895, pl. xii, fig. 1 ; pl. xv, fig. 15.

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THE PHILLIPSI AND TENUIS ZONES

This upper fauna of large Anthracomyas with associated forms comparable with *A. pulchra* does not extend above the Worsley Four Foot. It marks the top of the Pulchra Zone of Davies and Trueman, and above this last mentioned seam we find ourselves in the base of the immense zone of *A. phillipsi*. This form appears, doubtfully, close above the seam and is found in full development some 40 or 50 feet above it. It appears to occupy this bed to the exclusion of all other forms of mollusca, and crushed specimens show a good deal of variation in outline, one variant of subcircular shape being worthy of mention, as it may possibly characterise the horizon.

Above this level, until we reach the Upper Coal Measures, present exposures are wanting and records are few. Walcot Gibson has recorded the occurrence of *A. phillipsi* in Rayner's Borehole about 1,000 feet above the position of the Worsley Four Foot, and it is also recorded from the roof of the Bradford Four Foot. In the Ardwick Series both *A. phillipsi* and *A. tenuis* are present, the latter being represented by some specimens from Plymouth Grove Boring, Manchester, preserved in the Manchester Museum. It has also been found by Mr. L. H. Tonks at 344 feet in the Seedley boring in Manchester.

The species described in this paper cover only a portion of the new material assembled in the course of the re-survey of the Manchester district. They have been chosen with great deliberation, having regard for their zonal importance, distinctive character and state of preservation. Dr. Trueman has been kind enough to spend some time in discussing this matter of selection with the writer, and has made valuable suggestions. He has also given every facility for ensuring that the use of specific names of earlier date is in conformity with his own practice. Miss Dix of University College, Swansea, has also taken much trouble with the same object in view. Any attempt to subdivide the group of *A. phillipsi* has been avoided, as Miss Dix and Dr. Trueman have in hand the revision of this group on the basis of material very superior to any obtained up to the present in Lancashire. Dr. J. W. Jackson has kindly given access to the extensive collection of the Manchester Museum, which contains a number of valuable types and figured specimens.

The zonal results discussed are the outcome of much energetic search for fossils on the part of the geologists of the Lancashire unit, and the stratigraphy which forms its basis has been entirely evolved by them. To Mr. L. H. Tonks who, in the use of *Carbonicola*-bands for the identification of strata, first broke ground in Lancashire with his brilliant and economically important correlation of the Bradford and Oldham fields, the writer's acknowledgments are especially due.

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Explanations of Plates I and II

The specimens illustrated in these plates are in the collection of the Geological Survey in London, except the original of Plate II, fig. 4, in the Manchester Museum. In all cases the register numbers of the specimens are cited, and these give reference to the particulars of locality and horizon in the descriptive text. All the figures are drawn in natural size except Pl. I, fig. 9.

Plate I

Fig.

1. *Anthracomya cymbula* sp. nov., type, 48636.
2. ,, *oblonga* sp. nov., type, 48637.
3. ,, *librata* sp. nov., holotype, 48646.
4. ,, *fisheri* sp. nov., type, 48653.
4A. ,, ,, front view of the same specimen.
4B. ,, ,, dorsal view of the same specimen.
5. *Carbonicola boltoni* sp. nov., paratype, 48648.
5A. ,, ,, front view of the same specimen.
5B. ,, ,, dorsal view of the same specimen.
6. *Carbonicola* aff. *boltoni* sp. nov., extreme variant, 48650.
7. *Carbonicola* aff. *boltoni* sp. nov., extreme variant, 48649.
8. ,, *radiata* sp. nov., holotype, 48641.
8A. ,, ,, longitudinal profile of the same specimen.
8B. ,, ,, vertical profile of the same specimen.
9. ,, *carissima* sp. nov., holotype, x 2; 48644.
9A. ,, ,, vertical profile of the same specimen.
10. ,, *acutella* sp. nov., holotype, 48647.
10A. ,, ,, longitudinal profile of the same specimen.
10B. ,, ,, vertical profile of the same specimen.
11. ,, *concinna* sp. nov., holotype, 48645.
11A. ,, ,, longitudinal profile of the same specimen.
11B. ,, ,, vertical profile of the same specimen.

Plate II

Fig.

1. *Carbonicola retrotracta* sp. nov., holotype (much idealized), 48642.
1A. ,, ,, front view of the same specimen.
1B. ,, ,, dorsal view of the same specimen.
2. ,, *elliptica* sp. nov., holotype, 48640.
2A. ,, ,, longitudinal profile of the same specimen.
2B. ,, ,, vertical profile of the same specimen.
3. ,, ,, paratype, 48639.
4. ,, *phrygiana* sp. nov., type, W.551, E. coll. Wild (Manchester).
4A. ,, ,, front view of the same specimen.
4B. ,, ,, dorsal view of the same specimen.
5. ,, *os-lancis* sp. nov., holotype, 48651.
5A. ,, ,, longitudinal profile of the same specimen.
5B. ,, ,, vertical profile of the same specimen.
6. ,, ,, paratype, 48643.
7. ,, ,, var. *pectorata* var. nov., type, 48652.
8. ,, *cycloquadrata* sp. nov., type, 48638.

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V.—FLORA AND STRATIGRAPHY OF THE BRISTOL AND SOMERSET COALFIELD

By R. Crookall, Ph.D.

Text-figures 1 and 2.

I. Introductory

The Bristol and Somerset Coalfield is of great interest,

(1) as including the type area of the Radstockian Series,

(2) as a field in which the Transition or Staffordian Series—now widely recognised in the British Coal Measures—is well developed,

(3) as an area in which the plant remains acquire additional stratigraphical importance from the fact that animal remains are comparatively scarce and restricted in distribution,

(4) as the strata associated with the Radstock Series probably represent the richest beds in fossil plants in Britain : there is a great variety of species, and the state of preservation is excellent,

(5) as in recent years, plant petrifications have been obtained.[1]

Although the coalfield is one of the best known in Britain, much work remains to be done, especially as, prior to 1925, almost all the plant records lack a definite horizon. Besides noting additional records, I have here brought together all the plants known from the area, at the same time indicating a number of necessary corrections. It has also been possible to make a suggestion as to the probable age of the Pennant Rock in the Northern portion of the coalfield, to confirm the reference of the New Rock and Vobster Series to the Blackband Group of the Staffordian Series, and of the upper beds of the so-called Millstone Grit to the Yorkian Series.

II. Description of Coalfield

The Bristol and Somerset Coalfield stretches about 26 miles from north to south and about 24 miles from east to west. The northern and southern limits are at Cromhall in Gloucestershire and Frome in Somersetshire, while the eastern and western limits are Bath and Nailsea.

Only about one-fifth of the approximately 150 square miles of Coal Measures are exposed at the surface, the remainder being covered unconformably by Jurassic and Triassic rocks.

[1] Crookall, R., ' Summary of Progress ' for 1926 (*Mem. Geol. Surv.*), 1927, p. 161.

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The Kingswood anticline, occurring between Bristol and Warmley, divides the field into a northern and a southern area, while the latter is further divided by the Farmborough Fault, which runs roughly east to west a little to the north of Camerton and Timsbury. Excluding the outlying Nailsea basin (which has not been worked for many years), this gives three well-marked tracts of Coal Measures :—

(1) The Northern or Gloucestershire Area, which is itself conveniently subdivided into two districts, namely, that to the north of Bristol (where the Parkfield and Coalpitheath Pits work), and that around Bristol (Kingswood and Bedminster Pits).

(2) The Central or Pensford Area (Pensford and Bromley Pits).

(3) The Southern or Radstock Area (the most productive part of the coalfield).

The Coal Measures are divided by 2,500–3,000 feet of Pennant Rock (a coarse grey sandstone) into what are known locally as the Upper and Lower Divisions. The former includes two groups of coals, the Radstock Series (of 8 seams) and the Farrington Series (of usually 6 seams), and between these are 540–720 feet of strata near the middle of which are beds of red shale from 130 to 250 feet in thickness. The upper division is not present throughout the area. The Lower division underlies the entire coalfield and includes the strata between the Pennant Rock and the so-called Millstone Grit. It contains about 37 seams, of which 26 have proved productive. These seams include the New Rock Series (about 18 thin seams) and the Vobster Series (of 8 or more seams), the latter being the lowest coals in the district, but there is no definite line of separation between the two Series. The Coal Measures include a total of about 140 coal-seams, but most of these are too thin to be worked profitably, while in the Radstock area many of the upper seams are now worked out. The facts are summarised in the following table :—

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STRATA AND COAL SEAMS

Division and approximate thickness	Coal-seams	Number of seams	Development
'UPPER DIVISION' (2,200 feet)	Radstock Series	8	In Southern or Radstock Area only
	Red Shales (130–250 feet)		
	Farrington Series	Usually 6	(*a*) In Southern or Radstock Area (*b*) In Central or Pensford Area (*c*) In Northern or Gloucestershire Area
PENNANT ROCK (2,500–3,000 feet)	None ?	—	Practically throughout coalfield
'LOWER DIVISION' (2,800 feet)	New Rock Series	18 or more	Throughout coalfield
	Vobster Series	8 or more	
'MILLSTONE GRIT' (900–1,000 feet)	None workable	—	Throughout coalfield

In the following table are given the collieries working in the various areas, together with the series of coals worked. It shows at a glance the most productive portions of the coalfield.

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PITS WORKING AND SERIES WORKED

	NORTHERN AREA		CENTRAL AREA (around Pensford)	SOUTHERN AREA (around Radstock, South of Farmborough Fault)
	North of Bristol (Gloucestershire)	around Bristol (Kingswood and Bedminster)		
RADSTOCK[1] SERIES	—	—	—	Wellsway Pit ; Priston Pit ; Camerton Pit ; Dunkerton Pit
BOTH RADSTOCK AND FARRINGTON SERIES[1]	—	—	—	Braysdown Pit; Kilmersdon Pit
FARRINGTON SERIES[1]	Parkfield Pit, Puckle-church ; Coalpitheath Colliery	— —	Broad Oak Colliery, Pensford ; Bromley Pit, near Pensford	Old Mills Pit ; Middle Pit ; Lower Writh-lington Pit ; Foxcote Pit ; Ludlow's Pit ; Norton Hill Pit[3] ; Marsh Lane Pit[3] ; Bishop Sutton New Pit[3]
PENNANT ROCK	—	—	—	—
NEW ROCK AND VOBSTER SERIES[2]	—	South Liberty Colliery, Bedminster ; Deep and Speedwell Pits, Kingswood	—	Mells Pit ; New Rock Pit ; Newbury Pit ; Holcombe Pit ;

[1] Locally known as the ' Upper Division ' of the Coal Measures.
[2] Locally known as the ' Lower Division ' of the Coal Measures.
[3] These pits probably work the Farrington Series.

III. FAUNAL HORIZONS IN THE BRISTOL AND SOMERSET COALFIELD

It has been observed above that animal remains are not only comparatively rare in this coalfield, but that they are of somewhat restricted distribution. This especially applies to the ' Upper Division,' and correlation of the coalfield by this means, in the present state of our knowledge, cannot be satisfactorily attempted.

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In 1907 and 1911, Dr. H. Bolton[1] published lists of marine animals occurring locally, chiefly in the 'Lower Division' at Ashton Vale Pit (now no longer working), and referred the beds to the Lower Coal Measures. The botanical data, however, which are available from the 'Lower Division' throughout the coalfield, conclusively show the beds to belong to the Blackband Group of the Staffordian Series.

With regard to distribution, the case of *Leaia* may be mentioned. *Leaia leidyi* var. *williamsoni* was recorded by Dr. Bolton[2] from Coalpitheath Colliery. It is there quite common in the roof of the High Vein, embedded in patches in a distinct smooth type of shale, and is often accompanied by the small detached sporophylls known as *Lepidostrobus minor* (Goode). In view of the great value in correlation of the animal remains occurring in some coalfields, I have repeatedly carefully searched for this shell in the roof of the corresponding seam at the neighbouring colliery of Parkfield, but without success. I have never found this shell at Parkfield, either in the corresponding seam (there known as the Hollybush and Great Vein, combining to form a six-foot seam) or on the rubbish heap. The results obtained by Dr. Bolton (on faunal grounds) and by myself (on floral evidence) may be compared as follows :—

SERIES	FAUNAL HORIZON[3]	FLORAL HORIZON
'Coalpitheath and Parkfield Series' (=Farrington Series)	True Lower Coal Measures	Newcastle Group of Staffordian Series
Pennant Rock ...	—	Staffordian Series
'Ashton and Bedminster Series of Bristol' (=Lower Division)	True Lower Coal Measures	Blackband Group of Staffordian Series
'Vobster Series of Radstock' (=Lower Division)	True Lower Coal Measures	Blackband Group of Staffordian Series

[1] Bolton, H., 'On a Marine Fauna in the Basement-beds of the Bristol Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxiii, 1907, p. 455, and 'Faunal Horizons in the Bristol Coalfield,' *Quart. Journ. Geol. Soc.*, vol. lxvii, 1911, p, 337.

[2] Bolton, H., 1911, *op. cit.*, p. 321.

[3] Bolton (*op. cit.*, 1911, p. 339) observes 'The accompanying synopsis . . . shows that the Ashton and Bedminster Series of Bristol, the Coalpitheath and Parkfield Series of the northern part of the coalfield, and the Vobster Series of Radstock which form the basement series of the Lower Coal-Measures, are all characterised by a fauna agreeing with the typical fauna of the Lower Coal Measures in the coalfields of the Midlands and of Lancashire and Yorkshire.'

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Dr. Bolton[1] observes, ' The marine fauna undergoes no marked change throughout—forms common in the Lower Coal Measures[2] ranging upwards, and not being replaced by new species. This lack of mutability will probably prevent the use of marine bands for zonal purposes. The continuity of life-forms in the Middle Coal Measures of Yorkshire is strikingly complete, less so in the Bristol Measures ; but even here the long interval represented by the deposition of over 1,000 feet of Pennant Grit has not sufficed to prevent their recurrence at higher levels.'

While Coal Measure animals may, in some coalfields, prove of greater value than plant-remains in the correlation of individual seams, the data thus provided are often of local application only, and fossil plants as a rule give the safest data for correlating isolated coalfields, both in Europe and America.[3]

IV. Plant Records

(1) The first systematic investigation of the coalfield was published in 1888 by the late Dr. R. Kidston[4] who dealt mainly with the Radstock Series, the records from the other rocks being merely incidental. Many of the localities from which Kidston obtained his plants have been out of working for a number of years, or are now working different seams or even a different series of coals. The records, with certain necessary corrections, are given below.

RADSTOCK SERIES

FUNGI

Excipulites callipteridis (*Schimper*) Loc. Radstock.

PTERIDOSPERMEAE & FILICALES

Acitheca polymorpha (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Camerton.

Alethopteris aquilina (*Schloth.*) Locs. Radstock, Braysdown, Wellsway.

,, davreuxi (*Brongt.*) Locs. Radstock, Camerton.

,, grandini (*Brongt.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre.

,, lonchitica (*Schloth.*) (records require confirmation) Locs. Radstock, Braysdown, Middle Pit.

,, serli (*Brongt.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Dunkerton, Camerton, Welton Hill, Huish.

Alloiopteris radstockensis *Kidst.* (recorded as *Corynepteris erosa*) Loc. Camerton.

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[1] Bolton, H., *op. cit.*, 1911, p. 340.

[2] In this coalfield the term ' Lower Coal Measures ' can be used in a local sense only : true Lower Coal Measures (in the palaeobotanical sense) are absent.

[3] With regard to this aspect of the subject, see also Pringle, J., and R. Crookall, ' On Fossils from the Coal Measures of Kent,' ' Summary of Progress ' for 1927, part ii (*Mem. Geol. Surv.*), 1928, p. 84.

[4] Kidston, R., ' On the Fossil Flora of the Radstock Series of the Somerset and Bristol Coalfield (Upper Coal Measures)', part 1, *Proc. Roy. Soc. Edinb.*, vol. xxxiii, pt. ii, 1888, pp. 335–417.

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Asterotheca abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*: Mr. Hemingway suggests that *A. abbreviata* is distinct from *A. miltoni*, and the records are here provisionally kept separate) Locs. Radstock, Braysdown, Wellsway, Lower Conygre, Camerton, Welton Hill.

,, arborescens (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Kilmersdon, Camerton.

,, candolleana (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Middle Pit.

,, crenulata (*Brongt.*) (recorded as *Pecopteris*) Loc. Camerton.

,, cyathea (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Upper Conygre.

,, lamuriana (*Heer*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown.

,, oreopteridia (*Schloth.*) (recorded as *Pecopteris*) Locs. Radstock, Wellsway, Braysdown, Upper Conygre, Camerton.

Crossotheca pinnatafida (*Gutb.*) (recorded as *Pecopteris*) Locs. Radstock, Upper Conygre, Camerton.

Dicksonites pluckeneti (*Schloth.*) Locs. Radstock, Upper Conygre, Kilmersdon, Welton Hill.

Diplotmema geniculatum (*Germ. & Kaul*) (recorded as *Sphenopteris*) Locs. Kilmersdon, Camerton.

Eupecopteris bucklandi (*Brongt.*) (recorded as *Pecopteris*) Loc. Camerton.

,, cisti (*Brongt.*) (recorded as *Pecopteris*) Loc. Dunkerton.

,, dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*. Mr. Hemingway suggests that *E. dentata* is distinct from *D. plumosa*, and they are here provisionally kept apart). Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Camerton.

,, pteroides (*Brongt.*) (recorded as *Pecopteris*) Loc. ' near Bath.'

,, villosa (*Brongt.*) (recorded as *Pecopteris*: type of species) Loc. Camerton.

Linopteris munsteri (*Eichw.*) (recorded as *Dictyopteris*) Loc. Camerton.

Macrosphenopteris lindsaeoides *Kidst.* Loc. Radstock.

Mariopteris (the species of this genus previously recorded were revised by Kidston in 1925, and these records only will be given).

Neuropteris fimbriata *Lesqx.* Locs. Wellsway, Upper Conygre, Camerton.

,, flexuosa *Sternb.* Locs. Radstock, Upper Conygre, Lower Conygre, Camerton.

,, macrophylla *Brongt.* Locs. Radstock, Braysdown, Wellsway Upper Conygre, Lower Conygre, Kilmersdon, Dunkerton.

,, obliqua (*Brongt.*) (recorded as *Alethopteris obliqua*—from Camerton—record should probably be suppressed).

,, ovata *Hoffm.* Locs. Radstock, Wellsway, Upper Conygre, Camerton.

,, rarinervis *Bunb.* Locs. Radstock, Wellsway, Upper Conygre, Lower Conygre, Camerton.

,, scheuchzeri *Hoffm.* Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Camerton.

Odontopteris lindleyana (*L. & H.*) Locs. Radstock, Braysdown.

Pecopteris aspera *Brongt.* (Kidston's doubtful record of this species from Upper Conygre Pit should probably be suppressed).

,, pennaeformis *Brongt.* (Kidston's record of *P. pennaeformis* = *Senftenbergia ophiodermatica*, from Camerton should be suppressed: the species has not yet been recorded from Britain).

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Ptychocarpus unitus (*Brongt.*) (recorded as *Pecopteris*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Lower Conygre, Kilmersdon, Camerton.

,, ,, forma emarginata *Goepp.* Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Camerton.

Radstockia sphenopteroides (*Kidst.*) (recorded as *Schizostachys*) Loc. Radstock.

Sphenopteris alata *Brongt.* (recorded as *S. grandini*) Locs. Radstock, Braysdown, Lower Conygre, Kilmersdon.

,, cristata *Brongt.* (record from Camerton has been described as *Mariopteris plumosa*).

,, macilenta *L. & H.* Locs. Radstock, Braysdown, Camerton,

,, neuropteroides *Boulay* Locs. Radstock, Camerton, Withy. Clandown.

,, sewardi *Kidst.* (recorded as *S. tenuifolia*) Loc. Upper Conygre.

,, trifoliolata *Artis* (record from Deep Pit omitted from Kidston Memoir and should be suppressed).

,, woodwardi *Kidst.* Loc. Camerton.

Unatheca oblonga *Kidst.* (recorded as *Ptychocarpus oblongus*) Loc. Camerton.

PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS

Aphlebia crispa (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Braysdown, Camerton.

,, filiciformis (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Radstock, Camerton.

,, goldenbergi *Weiss* (recorded as *Rhacophyllum*) Loc. Radstock.

,, spinosa *Lesqx.* (recorded as *Rhacophyllum*) Loc. Radstock.

Caulopteris anglica *Kidst.* Locs. Radstock, Camerton.

,, peltigera (*Brongt.*) (recorded as *C. macrodiscus*) Locs. Radstock, Camerton.

,, primaeva *L. & H.* Locs. Radstock, Camerton.

,, sp. Locs. Radstock, Camerton.

Megaphyton elongatum *Kidst.* Loc. Radstock.

,, frondosum *Artis* Locs. Radstock, Camerton, Middle Pit.

Spiropteris sp. Loc. Braysdown.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Locs. Braysdown, Lower Writhlington.

Lepidodendron aculeatum *Sternb.* Locs. Radstock, Braysdown, Wellsway, Camerton.

,, lanceolatum *Lesqx.* Locs. Radstock, Braysdown, Upper Conygre, Camerton.

,, rhombicum (*Sternb.*) Loc. Upper Conygre.

,, wortheni *Lesqx.* Locs. Radstock, Braysdown, Wellsway, Camerton.

Lepidophloios sp. Locs. Radstock, Camerton.

Lepidophyllum brevifolium *Lesqx.* (recorded as *Lepidophyllum sp.*) Locs. Radstock, Braysdown.

,, majus *Brongt.* Locs. Radstock, Upper Conygre, Camerton.

Lepidostrobus ? spinosus *Kidst.* Loc. Braysdown.

,, sp. Loc. Radstock.

Lycopod macrospores. Loc. Radstock.

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Sigillaria alternans *Sternb.* Locs. Radstock, Braysdown.
,, cumulata *Weiss* (recorded as *S. tessellata*) Locs. Radstock, Braysdown, Camerton.
,, ,, forma nodosa *Bowman* Loc. Braysdown.
,, laevigata *Brongt.* Locs. Radstock, Braysdown.
,, major *L. & H.* Loc. Radstock.
,, mc'murtriei *Kidst.* Locs. Radstock, Braysdown.
,, notata *Brongt.* Loc. Dunkerton.
,, reniformis *Brongt.* Loc. Radstock.
,, ,, forma radstockensis *Kidst.* Loc. Radstock.
,, serli *Brongt.* Loc. Radstock.
Stigmaria anglica (*Sternb.*) Locs. Radstock, Camerton, Paulton.
,, ficoides (*Sternb.*) Locs. Radstock, Lower Conygre, Kilmersdon, Welton Hill.
,, ,, forma minor *Gein.* Loc. Braysdown.

EQUISETALES

Annularia sphenophylloides (*Zenk.*) Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Kilmersdon, Camerton.
,, stellata (*Schloth.*) Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Kilmersdon, Camerton, Paulton.
Asterophyllites equisetiformis (*Schloth.*) Locs. Radstock, Braysdown, Wellsway, Upper Conygre, Kilmersdon.
Calamites carinatus *Sternb.* (recorded as *C. ramosus*) Locs. Radstock, Camerton, Upper Conygre, Kilmersdon.
,, cisti *Brongt.* Locs. Radstock, Braysdown, Wellsway, Lower Writhlington, Camerton.
,, multiramis *Weiss* (*K. & J.*) (recorded as *C. cruciatus senarius*) Loc. Camerton.
,, suckowi *Brongt.* Locs. Radstock, Camerton.
,, undulatus *Sternb.* (recorded as *C. varians* var. *insignis*) Loc. Camerton.
,, sp. (recorded as *C. cannaeformis*) Locs. Camerton, Welton Hill.
Calamostachys tuberculata (*Sternb.*) (recorded as *Stachannularia*) Loc. Radstock.
Macrostachya infundibuliformis (*Brongt.*) Locs. Radstock, Kilmersdon.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Locs. Radstock, Braysdown, Upper Conygre, Lower Conygre, Camerton, Paulton.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Locs. Radstock, Upper Conygre, Camerton.
Poacordaites microstachys (*Gold.*) Locs. Radstock, Braysdown.

SEMINA INCERTAE SEDIS

Carpolithus membranaceus *Goepp.* (recorded as *C. ovoideus*) Locs. Wellsway, Camerton.
,, sp. Loc. Upper Conygre.
Cordaicarpus gutbieri *Gein.* Loc. Radstock.
Holcospermum multistriatum (*Presl.*) (recorded as *Rhabdocarpus*) Loc. Radstock.
Samaropsis fluitans (*Dawson*) (recorded as *Cardiocarpus*—these records require confirmation) Loc. Upper Conygre.
Trigonocarpus ? dawesii *L. & H.* Loc. Camerton.
,, noeggerathi (*Sternb.*) Locs. Radstock, Upper Conygre, Camerton.

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INCERTAE SEDIS

Sporangia. Locs. Upper Conygre, ? Welton Hill.

FARRINGTON SERIES

PTERIDOSPERMEAE AND FILICALES

Alethopteris grandini (*Brongt.*) Loc. Old Mills.
,, lonchitica (*Schloth.*) (records require confirmation). Locs. Top Vein, Parkfield, Middle Pit.
,, serli (*Brongt.*). Locs. Old Mills, Farrington, Middle Pit.
Asterotheca arborescens (*Schloth.*) (recorded as *Pecopteris*) Locs. Parkfield, Old Mills.
,, oreopteridia (*Schloth.*) (recorded as *Pecopteris*) Locs. Parkfield, Farrington.
Dicksonites pluckeneti (*Schloth.*) Locs. Foxcote, Farrington.
cf. Diplotmema zeilleri *Stur* (recorded as *Sphenopteris sp.*) Loc. Old Mills.
Eupecopteris pteroides (*Brongt.*) (recorded as *Pecopteris*, but record should be suppressed) Loc. Parkfield.
Neuropteris flexuosa *Sternb.* Loc. Old Mills.
,, macrophylla *Brongt.* Locs. Top Vein, Parkfield, Old Mills, Farrington.
,, ovata *Hoffm.* Locs. Hollybush Vein, Parkfield, Old Mills.
,, rarinervis *Bunb.* Locs. Foxcote, Old Mills.
,, scheuchzeri *Hoffm.* Locs. Foxcote, Old Mills, Farrington, Middle Pit.
Ptychocarpus unitus (*Brongt.*) (recorded as *Pecopteris*). Locs. Old Mills, Farrington.
Sphenopteris macilenta *L. & H.* Loc. Old Mills.
,, neuropteroides *Boul.* Loc. Old Mills.
,, sp. Loc. Old Mills.
Aphlebia crispa (*Gutb.*) (recorded as *Rhacophyllum*) Locs. Parkfield, ? Old Mills.
,, goldenbergi *Weiss* (recorded as *Rhacophyllum*) Loc. Parkfield.
,, sp. (recorded as *Rhacophyllum*). Loc. Farrington.
Caulopteris peltigera (*Brongt.*) (recorded as *C. macrodiscus*) Loc. Coalpitheath.
,, sp. Loc. Old Mills.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Loc. Old Mills.
Lepidodendron wortheni *Lesqx.* Loc. Old Mills.
Lepidostrobus sp. Loc. Old Mills.
Sigillaria cumulata *Weiss* (recorded as *S. tessellata*) Loc. Foxcote.
,, elongata forma minor *Bgt.* Loc. Parkfield.
,, mc'murtriei *Kidst.* Loc. Farrington.
,, reniformis *Brongt.* Loc. Coalpitheath.
,, voltzi *Brongt.* Loc. Coalpitheath.
Stigmaria ficoides (*Sternb.*) Locs. Parkfield, Foxcote, Old Mills.

EQUISETALES

Annularia sphenophylloides (*Zenk.*) Loc. Old Mills.
,, stellata (*Schloth.*) Locs. Parkfield, Old Mills, Farrington.
Calamites carinatus *Sternb.* (recorded as *C. ramosus*) Loc. Parkfield.
,, suckowi *Brongt.* Loc. Farrington.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Locs. Parkfield, Old Mills, Farrington.

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CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Locs. Foxcote, Old Mills.

SEMINA INCERTAE SEDIS

Carpolithus membranaceus *Goepp.* (recorded as *C. ovoideus*) Loc. Old Mills.
Samaropsis fluitans (*Dawson*) (recorded as *Cardiocarpus*—record doubtful). Loc. Old Mills.
Trigonocarpus noeggerathi (*Sternb.*). Loc. Old Mills.

PENNANT ROCK

LYCOPODIALES

Lepidostrobus sp. Loc. Downend.
Stigmaria ficoides (*Sternb.*). Loc. ?

EQUISETALES

Calamites schutzeiformis *K. & J.* forma waldenburgensis (recorded as *C. approximatus*) Locs. Crewshole, Downend, Fishponds.
,, suckowi *Brongt.* Loc. Crewshole.
,, sp. (recorded as *C. cannaeformis*) Loc. Crewshole.

NEW ROCK SERIES

PTERIDOSPERMEAE AND FILICALES

Asterotheca arborescens (*Schloth.*) (recorded from Golden Valley as *Pecopteris*—record should be suppressed).
,, abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*—provisionally referred to *A. abbreviata*). Locs. Top Vein, Warmley, Golden Valley.

LYCOPODIALES

Asolanus camptotaenia *Wood* (recorded as *Sigillaria monostigma*) Loc. Warmley.
Lepidophloios sp. (recorded as *Halonia*) Loc. Fishponds.
Lepidostrobus sp. Loc. Speedwell.
Sigillaria cumulata *Weiss* Loc. ? Kingswood.
,, elongata *Brongt.* (recorded as *S. rugosa*). Loc. Kingswood.
,, major *L. & H.* Loc. Little Toad Vein, ? Speedwell.
,, mammillaris *Brongt.* Loc. Warmley.
,, ,, forma abbreviata *Weiss* Loc. Great Toad Vein, Kingswood.
,, scutellata *Brongt.* Loc. Kingswood.
,, tenuis *Achepohl* (recorded as *S. schlotheimii*) Loc. Top Vein, Kingswood.
Stigmaria ficoides (*Sternb.*) Locs. Kingswood, Bedminster.

EQUISETALES

Calamites suckowi *Brongt.* Loc. Thoroughfare Seam, Kingswood.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury.* Loc. Deep Pit.
,, sp. Loc. Kingswood.

VOBSTER SERIES

PTERIDOSPERMEAE AND FILICALES

Asterotheca oreopteridia (*Schloth.*) (recorded as *Peceopteris* from Ashton—record should be deleted).

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LYCOPODIALES

Lepidodendron aculeatum *Sternb.* Loc. Edford.
,, rimosum *Sternb.* Loc. between Stone Rag and Main Seam, Edford.
Sigillaria mammillaris *Brongt.* Loc. Ashton.
,, rugosa *Brongt.* (recorded as *S. sillimanni*) Loc. Ashton.

EQUISETALES

Calamites undulatus *Sternb.* (recorded as *C. varians* var. *insignis*) Loc. Edford.
,, sp. (recorded as *C. cannaeformis*). Loc. Edford.

SPHENOPHYLLALES

Sphenophyllum emarginatum *Brongt.* Loc. Ashton.

(2) A number of subsequent records from the Bristol and Somerset Coalfield are due to Kidston. In *Summary of Progress* for 1913[1] he gave a list of plants from a boring at Hemington, Somerset, which, however, contained no species hitherto unrecorded from the coalfield. On stratigraphical grounds, the horizon from which they were obtained was regarded as probably the Farrington Series, but the species listed are common to both the Radstock and the Farrington Series. In 1921, Kidston[2] recorded the following species from a boring at Yate, Gloucestershire, the plants coming from the ' Lower Division ' of coals.

	Depths in feet
Corynepteris coralloides (*Gutbier*)	1,909
Linopteris *cf.* obliqua (*Bunbury*)	1,171
Lonchopteris bricei *Brongt.*	1,974
Mariopteris sp.	1,171
Neuropteris tenuifolia (*Schloth.*)	1,525, 1,711
,, sp.	1,525, 1,697 1,711, 1,719
Pecopteris (Dactylotheca ?) sp.	1,697
,, sp.	1,525,[3]1,562
,, striata *Gothan*[4]	1,711
,, sp.	1,804-1,810
Calamites cisti *Brongt.*	1,804-1,810
,, sp.	1,804-1,810
Annularia microphylla *Sauveur*	1,909
Asterophyllites equisetiformis (*Schloth.*)...	1,525
Palaeostachya sp.	1,973
Lepidostrobus lanceolatus (*L. & H.*)[5]	1,711
Sigillaria mammillaris *Brongt.*	1,510
Cordaites principalis (*Germar*)	1,525
,, sp.	1,711, 1,804, 1,810

[1] Kidston, R., ' Note on Fossil Plants met with in a Boring for Coal at Hemington, Somerset,' ' Summary of Progress ' for 1913, (*Mem. Geol. Surv.*), 1914, p. 101.
[2] Kidston, R., in Pringle, J., ' On a Boring for Coal, at Yate, Gloucestershire,' ' Summary of Progress ' for 1920 (*Mem. Geol. Surv.*), 1921, p. 95.
[3] Recorded as *S. cf artemisaefolioides* Crepin, but the plant appears to be absent from Britain.
[4] Specimen recorded as *S. obtusiloba* Brongt., but the British fossils referred to this species by Kidston were later recognised as distinct and referred to *S. striata.*
[5] Recorded as *Lepidophyllum lanceolatum.*

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In 1917, Kidston and Jongmans[1] mentioned the following additional species of *Calamites* from the coalfield.

Calamites schutzeiformis *K. & J.* forma typicus from Camerton.
,, ,, ,, ,, waldenburgensis *Kidst. pro sp.* from Radstock.
,, carinatus *Sternb.* from Farrington and Kingswood.
,, undulatus *Sternb.* from Deep Pit.

Kidston noted the following additions to the flora in his Memoir on Fossil Plants of the Carboniferous Rocks of Great Britain.[2]

Sphenopteris alata *Brongt.* Loc. Middle Pit.
,, pecopteroides *Kidst.* Loc. Kilmersdon.
Unatheca oblonga *Kidst.* Loc. Lower Conygre.
Eupecopteris dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*, provisionally referred to *E. dentata*) Loc. Kilmersdon.
Dicksonites pluckeneti (*Schloth.*) Loc. Braysdown.
Asterotheca arborescens (*Schloth.*) Loc. Coalpitheath.
,, cyathea (*Schloth.*) Loc. Wellsway.
,, abbreviata (*Brongt.*) Loc. Farrington.
,, hemitelioides (*Brongt.*) Locs. Radstock, Kilmersdon, Upper Conygre, Camerton.
,, lepidorachis (*Brongt.*) Loc. Camerton.
,, daubreei (*Zeiller*) Locs. Radstock, Wellsway.
Ptychocarpus unitus (*Brongt.*) Loc. Norton Hill.
Eupecopteris bucklandi (*Brongt.*) Loc. Radstock.
,, cisti (*Brongt.*) Locs. Braysdown, Coalpitheath.
,, fletti *Kidst.* Locs. Radstock, Wellsway, Camerton.
,, camertonesis *Kidst.* Loc. Camerton.
Pecopteris armasi *Zeiller* Loc. Wellsway.
Mariopteris nervosa (*Brongt.*) Loc. Radstock, Deep Pit.
,, plumosa *Kidst.* Loc. Camerton.

(3) In 1910, D. G. Lillie[3] investigated the flora of Farrington Series of the northern area of the coalfield, his fossils being obtained from the spoil heaps, so that their horizons are unknown. We note the following records :—

PTERIDOSPERMEAE AND FILICALES

Acitheca polymorpha (*Brongt.*) (recorded as *Pecopteris*) Loc. Coalpitheath.
Alethopteris serli (*Brongt.*) Loc. Shortwood.
Asterotheca crenulata (*Brongt.*) (recorded as *Pecopteris*) Loc. Coalpitheath.
,, abbreviata (*Brongt.*) (recorded as *Pecopteris miltoni*—provisionally referred to *A. abbreviata*) Locs. Coalpitheath, Parkfield, Shortwood.
Eupecopteris dentata (*Brongt.*) (recorded as *Dactylotheca plumosa*—provisionally referred to *E. dentata*) Loc. Shortwood.
? Macrosphenopteris sp. Loc. Parkfield.

[1] Kidston, R., and, W. J. Jongmans, Monograph of Calamites of Western Europe, Vol. I of the *Flora of the Carboniferous of the Netherlands and Adjacent Regions*, by W. J. Jongmans, atlas, plates, 1915, text, 1917. Gravenhage.
[2] Kidston, R., 'Fossil Plants of the Carboniferous Rocks of Great Britain' (*Mem. Geol. Surv.*) Palaeontology, vol. ii, 1923-1925 (parts 1-6).
[3] Lillie, D. G., ' Notes on the Fossil Flora of the Bristol Coalfield,' *Geol. Mag.*, N.S., decade v, vol. vii, 1910, pp. 58-67.

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Mariopteris sp. (recorded as *M. muricata*—record requires confirmation) Loc. Coalpitheath.
Neuropteris flexuosa *Sternb.* Loc. Parkfield.
,, scheuchzeri *Hoffm.* Loc. Coalpitheath.
Sphenopteris neuropteroides *Boulay* Locs. Coalpitheath, Parkfield.
,, ovatifolia *Lillie* Locs. Coalpitheath, Shortwood.
Aphlebia crispa (*Gutb.*) (recorded as *Schizopteris lactuca*) Loc. Coalpitheath.
,, spinosa *Lesqx.* (recorded as *Rhacophyllum*) Loc. Parkfield.

LYCOPODIALES

Lepidodendron lanceolatum *Lesqx.* Locs. Coalpitheath, Shortwood.
,, sp. (recorded as cf. *L. glincanum*, a species which occurs very rarely in Lower Carboniferous rocks only) Loc. Parkfield.

CORDAITALES

Cordaites angulosostriatus *Grand 'Eury* Loc. Coalpitheath.
Lepidophyllum majus *Brongt.* Loc. Coalpitheath.

(4) The following list of plants, identified by J. Pringle, occurs in an account of a boring at Winterbourne, Gloucestershire.[1]

	Depths in feet
Alethopteris lonchitica (*Schloth.*)	2,220
Linopteris obliqua (*Bunb.*)	1,200, 1,343
Neuropteris heterophylla *Brongt.*	2,130, 2,220, 2,280
Asterotheca miltoni (*Artis*)[2]	1,200
Pecopteris sp.	1,200
Sphenopteris sp.[3]	1,200, 2,160
,, trifoliolata (*Artis*)	2,121, 2,131
Calamites sp.	1,200, 2,231
Asterophyllites equisetiformis (*Schloth.*)...	1,200, 1,258
,, sp.	1,200
Sphenophyllum cuneifolium (*Sternb.*)	1,809
Palaeostachya sp.	1,809
Lepidostrobus minus (*Goode*)[4]	1,090
Cordaites principalis (*Germar*)	1,200, 2,130
,, sp.	2,191

(5) In 1914, the late Dr. E. A. N. Arber[5] mentioned several species of seeds from the coalfield; while he later recorded[6] a few examples of *Lepidostrobus* :—

[1] Cantrill, T. C., and Smith, B., 'On a Boring for Coal at Winterbourne, Gloucestershire,' ' Summary of Progress' for 1918 (*Mem. Geol. Surv.*), 1919, pp. 53-57.
[2] Recorded as *Pecopteris miltoni*.
[3] One specimen recorded as *S. cf. elegans* Brongt., but cannot belong to that species, which is a Lower Carboniferous form now known as *Diplotmema adiantoides* (Schl.).
[4] Recorded as *Lepidophyllum minus*.
[5] Arber, E. A. N., *Ann. of Botany*, 1914, vol. xxviii, pp. 96, 98, 101.
[6] Arber, E. A. N., *Journ. Linn. Soc.*, 1922, vol. xlvi, pp. 178, 180, 186.

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Samaropsis sp. (recorded as *S. fluitans*, but Kidston, *Proc. Roy. Soc. Edin.* vol. li, pt. iv, No. 27, p. 1031, disagreed with the specific determination) Loc. Camerton.

Holcospermum rugosum (*Arber*) (recorded as *Platyspermum*) Loc. Radstock.

Carpolithus sp. (recorded as *Radiospermum elongatum* n. sp., but *Radiospermum* is an unsatisfactory genus: the specimen will need to be re-examined) Locs. Radstock, Bishop Sutton.

,, ,, (recorded as *Radiospermum grande* n. sp.) Loc. Radstock.

Rhabdocarpus lillianus *Arber* Loc. Coalpitheath.

Lepidostrobus brevifolius *Lesqx.* Loc. Coalpitheath.

,, ? spinosus *Kidst.* Loc. Radstock.

,, lanceolatus (*L. & H.*) Loc. Radstock.

,, hastatus *Lesqx.* Loc. Coalpitheath.

(6) In 1925, the writer[1] published the results of an investigation which covered the whole coalfield. Special attention was paid to the northern area, the Central Area around Pensford and to the upper beds of the 'Millstone Grit.' Beyond the following notes and corrections, these records do not require repeating here.

PTERIDOSPERMEAE AND FILICALES

p. 149—*Pecopteris miltoni* is here provisionally recorded as *Asterotheca abbreviata.*

pp. 149, 151, 153, 154, 386—*Dactylotheca plumosa* is here provisionally referred to as *Eupecopteris dentata.*

pp. 149, 151, 153, 386—The records of Mariopteris require revising, and are here given as *Mariopteris sp.*

p. 149—The *Sphenopteris sp.* from Midsomer Norton is a new species awaiting description.

p. 151—*Alethopteris cf. integra*: this is *Pecopteris sp.*

pp. 155, 386—*Dictyopteris=Linopteris.*

p. 157—*Odontopteris conwayi=Margaritopteris conwayi.*

p. 385—*Sphenopteris ? sauveuri=Sphenopteris sp.*

p. 386—? *Oligocarpia brongniarti=Sphenopteris sp.*

LYCOPODIALES

pp. 150, 152—*Lepidophloios laricinus*: specific determination requires confirmation.

pp. 152, 387—*Lepidodendron loricatum=L. dichotomum* Zeiller.

SPHENOPHYLLALES

p. 387—*Sphenophyllum fasciculatum*: this specimen is probably a new species.

p. 387—*Sphenophyllum ? oblongifolium*; recorded as *Sphenophyllum sp.*

EQUISETALES

p. 154—*Stachannularia tuberculata=Calamostachys.*

SEMINA INCERTAE SEDIS

pp. 148, 153, 386—*Cyclopteris orbicularis*: specific determination probably incorrect: here recorded as *Cyclopteris sp.*

p. 150—*Schizospermum noeggerathi=Trigonocarpus.*

[1] Crookall, R., 'On the Fossil Flora of the Bristol and Somerset Coalfield,' 1925, *Geol. Mag.*, vol. lxii, pt. 1, pp. 145–180, pt. ii, pp. 385–410.

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p. 155—*Megalospermum inflatum*=*Carpolithus*.
p. 156—*Cordaicarpus areolatus*=*Carpolithus*.
p. 386—? *Radiospermum grande*=*Carpolithus sp.*
p. 387—*Radiospermum perpusillum*=*Carpolithus*.
p. 387—*Cordaicarpus ovoideus*=*C. membranaceus*.

PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS

p. 148—*Caulopteris cisti*=*C. peltigera*.

(7) There are a number of additional records to be made to the flora of the coalfield. Many of these specimens have been submitted to me for identification from time to time, others represent my own collecting.

RADSTOCK SERIES.—Mr. A. W. Coysh, B.Sc., collected the following plants from Clandown Pit, near Radstock, and the records are of value as this pit ceased working some time ago.

Sphenopteris macilenta *L. & H.*
Asterotheca abbreviata (*Brongt.*).
Eupecopteris camertonensis *Kidston.*
Eupecopteris sp.
Neuropteris scheuchzeri *Hoffm.*
Neuropteris flexuosa *Sternb.*
Mariopteris sp.
Sphenophyllum emarginatum *Brongt.*
Stigmaria ficoides (*Sternb.*).

FARRINGTON SERIES

Horizon : Middle Seam (Keele Group).
Locality : Norton Hill Pit, Midsomer Norton, near Radstock.
Lepidodendron aculeatum *Sternb.*
Horizon : ?
Locality : Broad Oak Colliery, Pensford.
Odontopteris britannica *Gutb.* (=Neuropteris obliqua (*Brongt.*)).

PENNANT ROCK (Staffordian Series)

Locality : Sandford (or Conygre) Quarry, Sandford, near Bristol.
Calamites suckowi *Brongt.*
Calamites sp.
Lepidodendron sp.
Stigmaria ficoides (*Sternb.*).
Locality : Staplehill, near Bristol.
Artisia transversa (*Artis*).
Artisia approximata (*Brongt.*).
Locality : Blue Pennant Quarry, Fishponds, Bristol.
Lepidodendron sp. (in Lyginodendroid condition).
Sigillaria sp.
Locality : Hanham Quarry, Bristol.
Calamites sp.
Lepidodendron sp. (in Lyginodendroid condition).
Sigillaria sp.

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Locality: Temple Cloud Quarry, Somerset.
Neuropteris sp.
Neuropteris scheuchzeri *Hoffm.*
Neuropteris rarinervis *Bunb.*
Calamites suckowi *Brongt.*
Calamites cf. undulatus *Sternb.*
Sphenophyllum saxifragaefolium (*Sternb.*)
Lepidodendron sp.
Sigillaria sp.

VOBSTER SERIES

Locality: Hanham Pit (now no longer working).
Cordaites principalis (*Germar*).

'MILLSTONE GRIT'

Locality: Wick Rocks, near Bristol. (Collected by Mr. A. W. Coysh).
Neuropteris obliqua (*Brongt.*)—common.
Renaultia chaerophylloides (*Brongt.*)—very rare.
Sphenophyllum cf. trichomatosum *Stur*—very rare.
Stigmaria ficoides (*Sternb.*)—very common.
Dorycordaites palmaeformis (*Goepp.*)—very rare.

Locality: Celestine Workings, Yate, near Bristol. (Collected by Dr. Stanley Smith).
Neuropteris schlehani *Stur.*

From the disturbed ground in the Great Western Railway Cutting at Cattybrook, near Pilning, Gloucestershire, Professor S. H. Reynolds and Dr. Stanley Smith collected a number of specimens which were identified by the writer as *Stigmaria ficoides* (Sternb.), *Sigillaria* sp., Lycopod megaspores, *Calamites undulatus* Sternb., *C. suckowi* Brongt., *Calamites sp.*, *Annularia? radiata* Brongt., and *Cordaites principalis* (Germar.)

LOWER CARBONIFEROUS (grit, etc., between Limestones D 1 and D 2—collected by Dr. Stanley Smith).

Locality: Wick Rocks, near Bristol.
Rachis of Fern or Pteridosperm.
Lepidodendron sp. (in Lyginodendroid condition).

Dr. Smith observes that these plant remains were accompanied by a fairly high Lower Carboniferous fauna. It is to be hoped that better preserved plants will be found in these beds.

We are now in a position to draw up the complete known flora of the coalfield: this is given below, the Pennant Rock being taken as the main line of division.

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Complete Flora of Coalfield

I. 'UPPER DIVISION' (RADSTOCK AND FARRINGTON SERIES)

	Radstock Series	Farrington Series		
		North	Central	South
FUNGI				
Excipulites callipteridis (*Schimp.*)	x	x	x	–
PTERIDOSPERMEAE AND FILICALES				
Acitheca polymorpha (*Brongt.*)	x	x	x	x
Alethopteris aquilina (*Schloth.*)	x	x	x	x
,, cf. costei *Zeiller* ...	–	x	–	–
,, davreuxi (*Brongt.*)	x	x	x	x
,, grandini (*Brongt.*)	x	x	–	x
,, ? lonchitica (*Schloth.*)	x	x	–	x
,, pontica Zeiller ...	–	x	–	–
,, serli (*Brongt.*) ...	x	x	x	x
,, cf. valida *Boulay*	–	–	x	–
Alloiopteris radstockensis *Kidst.*	x	–	–	–
,, sp.	–	x	–	–
Asterothca abbreviata (*Brongt.*)	x	x	x	x
,, arborescens (*Schloth.*)	x	x	x	x
,, candolleana (*Brongt.*)	x	–	x	–
,, crenulata (*Brongt.*) ...	x	x	x	x
,, cyathea (*Schloth.*) ...	x	–	–	x
,, daubreei (*Zeiller*) ...	x	–	–	–
,, hemitelioides (*Brongt.*)	x	–	–	–
,, lamuriana (*Heer*)	x	–	–	–
,, lepidorachis (*Brongt.*)	x	–	–	–
,, oreopteridia (*Schloth.*)	x	x	x	x
Corynepteris sternbergi (*Ett.*) ...	–	–	x	?
Crossotheca crépini *Zeiller* ...	–	x	–	–
,, pinnatafida (*Gutb.*) ...	x	x	–	–
,, sp.	–	–	–	x
Dicksonites pluckeneti (*Schloth.*)	x	x	–	x
Diplotmema geniculatum (*Germ. & Kaul.*)	x	–	–	–
,, cf. zeilleri *Stur* ...	–	–	–	x
,, sp.	–	–	–	x
Dolerophyllum sp.	–	–	x	x
Eupecopteris bucklandi (*Brongt.*)	x	x	x	x
,, camertonensis *Kidst.*	x	–	x	–
,, cisti (*Brongt.*) ...	x	x	–	–
,, dentata (*Brongt.*)	x	x	x	x
,, fletti *Kidst.* ...	x	–	–	–
,, pteroides (*Brongt.*)	x	–	–	–
,, villosa (*Brongt.*) ...	x	–	–	–
,, sp.	x	x	–	–
Linopteris munsteri (*Eichw.*) ...	x	–	–	–
,, obliqua (*Bunb.*) ...	–	–	–	x
Macrosphenopteris lindsaeoides *Kidst.*	x	–	–	–
? Macrosphenopteris sp.	–	x	–	–

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Mariopteris nervosa (*Brongt.*) ...	x	–	–	–
,, plumosa *Kidst.* ...	x	–	–	–
,, sp.	x	x	x	x
Neuropteris fimbriata *Lesqx.* ...	x	x	x	x
,, flexuosa *Sternb.* ...	x	x	x	x
,, heterophylla *Brongt.*	–	–	x	?
,, macrophylla *Brongt.*	x	x	x	x
,, obliqua (*Brongt.*) ...	–	–	x	–
,, ovata *Hoffm.* ...	x	x	x	x
,, rarinervis *Bunb.* ...	x	x	x	x
,, scheuchzeri *Hoffm.*...	x	x	x	x
,, schlehani *Stur* ...	–	–	x	–
,, sp.	–	x	–	–
Odontopteris alpina (*Presl.*) ...	–	–	x	–
,, lindleyana (*L. & H.*)	x	–	x	x
,, sp.	–	–	x	–
Pecopteris armasi *Zeiller* ...	x	–	–	–
Ptychocarpus unitus (*Brongt.*) ...	x	x	x	x
Radstockia sphenopteroides (*Kidst.*)	x	x	–	–
,, sp.	–	x	–	?
Renaultia chaerophylloides (*Brongt.*)	-	x	x	–
,, sp.	–	–	x	–
Sphenopteris alata *Brongt.* ...	x	x	–	x
,, laurenti *Andrae* ...	–	–	x	–
,, macilenta *L. & H.*	x	–	x	x
,, neuropteroides *Boul.*	x	x	x	x
,, ovatifolia *Lillie* ...	–	x	–	?
,, pecopteroides *Kidst.*	x	x	–	–
,, sewardi *Kidst.* ...	x	–	–	–
,, woodwardi *Kidst.*	x	–	–	–
,, sp.	x	–	x	x
Unatheca oblonga *Kidst.* ...	x	–	–	x
DETACHED ? MICROSPOROPHYLLS				
? Whittleseya sp.	–	–	–	x
PTERIDOSPERMEAE AND FILICALES INCERTAE SEDIS				
Aphlebia crispa (*Gutb.*)	x	x	x	x
,, filiciformis (*Gutb.*) ...	x	–	–	–
,, goldenbergi *Weiss.* ...	x	x	–	–
,, spinosa *Lesqx.* ...	x	x	–	–
,, sp.	–	x	x	x
Caulopteris anglica *Kidst.* ...	x	–	–	–
,, peltigera (*Brongt.*) ...	x	x	–	–
,, primaeva *L. & H.* ...	x	–	–	–
,, sp.	x	–	–	x
Cyclopteris sp.	x	x	x	x

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Megaphyton elongatum *Kidst.* ...	x	–	–	–
,, frondosum *Artis*	x	–	–	–
,, sp.	–	?	–	–
Spiropteris sp.	x	–	x	–
LYCOPODIALES				
Asolanus camptotaenia *Wood*	x	x	–	x
Leipdodendron aculeatum *Sternb.*	x	x	x	x
,, dichotomum *Zeiller*	–	x	–	x
,, distans *Lesqx.* ...	–	–	x	–
,, cf. jaraczewski *Zeill.*	–	x	–	–
,, lanceolatum *Lesqx.*	x	x	x	x
,, obovatum *Sternb.*	–	x	x	–
,, rhombicum (*Sternb.*)	x	–	–	–
,, rimosum *Sternb.*	–	x	–	–
,, wortheni *Lesqx.*	x	x	x	x
,, sp.	–	x	x	x
Lepidophloios laricinus *Sternb.* ...	–	x	–	x
,, sp.	x	–	–	x
Lepidophyllum brevifolium *Lesqx.*	x	x	x	–
,, majus *Brongt.* ...	x	x	x	–
,, triangularis *Zeill.*	–	–	x	x
,, sp.	–	–	–	x
Lepidostrobus hastatus *Lesqx.* ...	–	x	–	–
,, lanceolatus (*L. & H.*)	x	x	x	x
,, minus (*Goode*) ...	x	x	x	x
,, ? spinosus *Kidst.*	x	–	–	–
,, sp.	x	–	x	x
Lycopod macrospores	x	x	–	x
Sigillaria alternans *Sternb.* ...	x	–	–	–
,, cumulata *Weiss* ...	x	–	x	x
,, deutschiana *Brongt.* ...	–	x	–	–
,, elongata *Brongt.* ...	–	x	–	–
,, ,, forma minor *Bt.*	–	x	–	–
,, cf. germanica *Weiss.* ...	–	–	x	–
,, kidstoni *Crookall*	–	–	x	–
,, laevigata *Brongt.* ...	x	–	–	–
,, major *L. & H.* ...	x	x	–	–
,, mammillaris *Brongt.*	–	x	–	–
,, mauricii *Grand'Eury* ...	–	–	x	–
,, mc'murtriei *Kidst.* ...	x	–	–	x
,, notata *Brongt.*	x	–	–	–
,, nortonensis *Crookall* ...	–	–	–	x
,, ovata *Sauveur*	?	–	x	x
,, principis *Weiss*... ...	–	–	–	x
,, reniformis *Brongt.* ...	x	x	–	–

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
Sigillaria rugosa *Brongt.*	–	x	–	–
,, serli *Brongt.*	x	–	–	–
,, transversalis *Brongt.* forma sparsifolia *Boul.*	–	–	x	–
,, voltzi *Brongt.*	–	x	–	–
,, sp.	x	–	–	x
Sigillariophyllum bicarinatum (*L. & H.*)	x	x	x	x
Sigillariostrobus sp.	x	–	–	–
Stigmaria anglica (*Sternb.*) ...	x	–	–	–
,, ficoides (*Sternb.*) ...	x	x	x	x
,, ,, forma minor *Gein.* ...	x	–	–	–
,, minuta *Goepp.* pro var.	–	x	–	–
EQUISETALES				
Annularia radiata *Brongt.* ...	–	x	x	–
,, sphenophylloides (*Zenk.*)	x	x	x	x
,, stellata (*Schloth.*) ...	x	x	x	x
Asterophyllites equisetiformis (*Schloth.*)	x	x	x	x
,, longifolius (*Sternb.*)	–	x	–	–
Calamites carinatus *Sternb.* ...	x	x	x	x
,, cisti *Brongt.*	x	x	–	–
,, multiramis *Weiss* (*K. & J.*)	x	–	–	–
,, schutzeiformis *K. & J.* forma typicus ...	x	–	–	–
,, forma waldenburgensis *Kidst.* pro. sp. ...	x	–	–	–
,, suckowi *Brongt.* ...	x	x	x	x
,, undulatus *Sternb.*	x	–	–	–
,, sp.	x	x	x	x
Macrostachya infundibuliformis (*Brongt.*)	x	?	–	–
Calamostachys tuberculata (*Sternb.*)	x	–	x	–
SPHENOPHYLLALES				
Sphenophyllum cuneifolium (*Sternb.*)	–	x	x	–
,, emarginatum *Brongt.*	x	x	x	x
,, cf. fasciculatum *Lesqx.* ...	–	–	x	–
,, majus *Bronn* ...	–	–	?	x
,, saxifragaefolium (*Sternb.*) ...	–	–	x	–
,, sp.	–	x	x	x

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'Upper Division'—*continued*

	Radstock Series	Farrington Series		
		North	Central	South
CORDAITALES				
Cordaites angulosostriatus *Grand 'Eury*	x	x	x	x
,, borassifolius (*Sternb.*)	–	–	x	–
,, principalis (*Germar*) ...	–	–	–	?
,, sp.	x	x	x	x
Poacordaites microstachys (*Gold.*)	x	–	x	–
SEMINA INCERTAE SEDIS				
Carpolithus membranaceus *Goepp.*	x	–	x	x
,, perpusillus *Lesqx.* ...	–	–	x	x
,, sp.	x	–	?	x
Cordaicarpus gutbieri *Gein.* ...	x	–	–	–
Holcospermum mammillatum *Lesqx.*	–	–	x	–
,, multistriatum (*Presl.*)	x	–	–	–
,, rugosum (*Arber*)	x	–	–	–
Rhabdocarpus lillianus *Arber* ...	–	x	–	–
Samaropsis cf. fluitans (*Dawson*)	x	–	–	x
,, sp.	–	–	x	x
Trigonocarpus dawesii *L. & H.* ...	x	–	–	–
,, noeggerathi (*Sternb.*)	x	x	–	x
,, parkinsoni *Brongt.*	–	–	x	x
,, sp.	–	x	–	–
INCERTAE SEDIS				
Pinnularia capillacea *L. & H.* ...	x	x	–	x
,, columnaris (*Artis*) ...	–	–	x	x
Sporangia	x	–	–	–

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II. PENNANT ROCK, 'LOWER DIVISION' AND 'MILLSTONE GRIT'

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
PTERIDOSPERMEAE AND FILICALES				
Alethopteris decurrens (*Artis*)	–	–	x	–
,, ? lonchitica (*Schl.*)	–	x	–	–
Asterotheca abbreviata (*Brongt.*)	x	x	–	–
,, arborescens (*Schl.*)...	–	x	–	–
Corynepteris coralloides (*Gutb.*)...	–	x	–	–
,, sternbergi (*Ett.*) ...	–	x	–	–
Crossotheca sp.	–	x	–	–
Desmopteris longifolia (*Stb.*) *Stur*	–	x	–	–
Diplotmema furcatum (*Brongt.*)	–	x	–	–
Dolerophyllum sp.	–	x	?	–
Eupecopteris dentata (*Brongt.*) ...	–	x	–	–
,, volkmanni (*Sauv.*)	–	x	–	–
Linopteris munsteri (*Eichw.*) ...	–	x	–	–
,, obliqua (*Bunb.*) ...	–	x	–	–
Lonchopteris bricei *Brongt.* ...	–	x	–	–
Margaritopteris conwayi (*L. & H.*)	–	–	–	x
Mariopteris nervosa (*Brongt.*) ...	–	x	–	–
,, sp.	–	x	x	–
Neuropteris heterophylla *Brongt.*	–	x	x	–
,, macrophylla *Brongt.*	–	x	–	–
,, obliqua *Brongt.* ...	–	x	–	x
,, pseudogigantea *Pot.*	–	x	?	–
,, rarinervis *Bunb.* ...	x	x	–	–
,, cf. raymondi *Zeill.* ...	–	x	–	–
,, scheuchzeri *Hoffm.*...	x	x	–	–
,, schlehani *Stur* ...	–	–	–	x
,, tenuifolia (*Schloth.*)	–	x	–	–
,, sp.	x	x	x	–
Pecopteris sp.	–	x	–	–
Renaultia chaerophylloides (*Bt.*)	–	–	–	x
Rhodea sp.	–	x	–	–
Sphenopteris dilatata *L. & H.* ...	–	x	–	–
,, laurenti *Andrae* ...	–	x	–	–
,, neuropteroides *Boul.*	–	x	–	–
,, striata *Gothan* ...	–	x	–	–
,, tenuissima *Presl.* ...	–	x	–	–
,, sp.	–	x	–	x
Unatheca oblonga *Kidst.* ...	–	x	–	–
Cyclopteris sp.	–	–	x	–
Spiropteris sp.	–	x	x	–
LYCOPODIALES				
Asolanus camptotaenia *Wood* ...	–	x	–	–
Lepidodendron aculeatum *Sternb.*	–	x	x	–
,, distans *Lesqx.* ...	–	–	–	x
,, lanceolatum *Lesqx.*	–	x	–	–
,, obovatum *Sternb.*	–	x	x	–
,, ophiurus *Brongt.*	–	x	–	–

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'Lower Division'—*continued*

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
Lepidodendron rimosum *Sternb.*	–	–	x	–
,, simile *Kidst.* ...	–	x	–	–
,, wortheni *Lesqx.*	–	x	–	–
,, sp.	x	x	x	–
Lepidophloios laricinus *Sternb.*	–	–	–	?
,, sp.	–	x	–	–
Lepidophyllum majus *Brongt.*	–	x	–	–
,, morissianum *Lesqx.*	–	x	–	–
,, triangularis *Zeiller*	–	x	–	–
,, sp.	–	x	–	x
Lepidostrobus incertus *Lesqx.* ...	–	x	–	–
,, lanceolatus (*L. & H.*)	–	x	–	x
,, minus (*Goode*) ...	–	x	–	–
,, radians *Schimper*	–	x	–	–
,, sp.	x	x	x	x
Lycopod macrospores	–	x	x	–
Sigillaria cordigera *Zeiller* ...	–	x	–	–
,, cumulata *Weiss* ...	–	?	–	–
,, elongata *Brongt.* ...	–	x	–	–
,, major *L. & H.* ...	x	x	–	–
,, mammillaris *Brongt.* ...	–	x	x	–
,, ,, forma abbreviata *Weiss*	–	x	–	–
,, ovata *Sauveur*	–	x	–	–
,, rugosa *Brongt.* ...	–	x	x	–
,, sauli *Brongt.*	–	x	–	–
,, scutellata *Brongt.* ...	–	x	–	–
,, tenuis *Achep.* ...	–	x	–	–
,, tessellata *Brongt.* ...	–	x	–	–
,, sp.	x	–	x	–
Sigillariophyllum bicarinatum (*L. & H.*)	–	x	x	x
Stigmaria ficoides (*Sternb.*) ...	x	x	x	x
,, minuta *Goepp.* pro var.	–	x	–	–
Bark of unknown Lycopod ...	–	x	–	–
EQUISETALES				
Annularia microphylla *Sauveur*	–	x	–	–
,, radiata *Brongt.* ...	–	x	–	–
,, sphenophylloides (*Zenk.*)	–	x	–	–
,, sp.	–	x	x	–
Asterophyllites charaeformis (*Sternb.*)	–	x	–	–
,, equisetiformis (*Schl.*)	–	x	–	–
,, grandis (*Sternb.*)	–	x	–	–

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'Lower Division'—*continued*

	Pennant Rock	'Lower Division'		'Millstone Grit'
		New Rock Series	Vobster Series	
Calamites carinatus *Sternb.* ...	–	x	–	–
,, cisti *Brongt.*	–	x	–	–
,, schützeiformis *K. & J.* forma waldenburgensis *Kidst.* pro sp.	x	–	–	–
,, suckowi *Brongt.* ...	x	x	x	–
,, undulatus *Sternb.* ...	?	x	x	x
,, sp.	x	x	x	x
Palaeostachya pedunculata *Will.*	–	x	–	–
,, sp.	–	x	–	–
SPHENOPHYLLALES				
Sphenophyllum cuneifolium (*Sternb.*)	x	x	x	–
,, emarginatum *Brongt.*	–	x	x	–
,, myriophyllum *Crépin*	–	x	–	–
,, saxifragaefolium (*Sternb.*)	–	x	–	–
,, trichomatosum *Stur*	–	x	–	x
CORDAITALES				
Astisia approximata (*Brongt.*)	x	x	–	–
,, transversa (*Artis*) ...	x	x	x	–
Cordaites angulosostriatus *Grand 'Eury*	–	x	–	–
,, borassifolius (*Sternb.*)	–	x	–	–
,, principalis (*Germar*) ...	–	x	x	–
,, sp.	–	x	x	–
Dorycordaites palmaeformis (*Goepp.*)	–	–	x	x
SEMINA INCERTAE SEDIS				
Carpolithus inflatus (*Lesqx.*) ...	–	x	–	–
,, membranaceus *Goepp.*	–	x	–	–
,, areolatus *Boulay*	–	x	–	–
,, sp.	–	x	–	–
Cordaicarpus cordai (*Gein.*) ...	–	x	–	–
Holcospermum sp.	–	x	–	–
Samaropsis sp.	–	x	–	–
Trigonocarpus sp.	–	x	–	–
INCERTAE SEDIS				
Pinnularia capillacea (*L. & H.*)	–	x	x	–
,, columnaris (*Artis*) ...	–	x	–	–

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V. General Observations

A glance at the tables given above will suffice to show that the Radstock Series is by far the most prolific in plant remains, and it constitutes one of the richest beds in the British Coal Measures. It is closely followed, in this respect, by the Farrington Series, especially that section which occurs in the Southern Area where the Radstock Series is also developed. The Farrington Series of the Northern and Central Area is less rich. In the Pennant Rock, as is to be expected from the nature of the sediments, plants are extremely scarce. The 'Lower Division' contains few plants and, although the New Rock Series has provided a fair number of species, these are all of rare occurrence. From the upper beds of the 'Millstone Grit' a comparatively few species (of Yorkian) plants have been recorded, but some of these are very common.

THE RADSTOCK SERIES

The flora of the Radstock Series indicates that these beds represent a transition between the Stephanian and Westphalian, with affinities towards the latter rather than towards the former.

THE FARRINGTON SERIES

In 1888, Kidston[1] observed that, 'Palaeontologically, the Farrington Series cannot be separated from the Radstock Series, of which, in fact, they seem to form a part.' Lillie[2] investigated the flora of the Farrington Series of the Northern or Gloucestershire Area, and referred it to the Upper Coal Measures (Radstockian Series). Prior to my work published in 1925,[3] the Farrington Series of the Central or Pensford Area had not been investigated. Until then the Farrington Series throughout the coalfield had been regarded as belonging to the Upper Coal Measures. The writer, however, showed[4] that the beds were of slightly different age in the different areas: Farrington Series of

Northern (Gloucestershire) Area = Newcastle Group of Staffordian Series,

Central (Pensford) Area = Newcastle Group of Staffordian Series,

Southern (Radstock) Area = Keele Group of Staffordian Series.

The Newcastle-under-Lyme Group represents the highest group of the Staffordian Series, while the Keele Group is the lower group of the Radstockian Series. It should here be pointed out that, on account of the reference of the Farrington Series of the Southern

[1] Kidston, R., 1888, *op. cit.*, p. 410.
[2] Lillie, D. G., 1910, *op. cit.*, p. 67.
[3] Crookall, R., 1925, *loc. cit.*
[4] Crookall, R., 1925, *op. cit.*, pp. 395, 398, 400.

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Area to the Keele Group, Kidston's division (given below) of the Radstockian Series into the three following groups requires revision:

RADSTOCKIAN SERIES { Radstock Group / Farrington Group / Keele Group

THE PENNANT ROCK

As has been observed above, the Pennant Rock is extremely barren of fossils. This is no doubt due to the porosity of the rocks which, readily admitting air and water, resulted in the almost complete decay of the enclosed vegetable matter. Moulds and casts are consequently the only common fossils. The coarseness of the rocks also militates against anything like excellence of preservation. The Pennant Rock may in part represent the Etruria Marl Group (which is also very barren of fossil plants). If this were so, in the Bristol district we should have a complete succession of the Staffordian Rocks.

Northern (Gloucestershire) Area	Group
Farrington Series	Newcastle-under-Lyme Group
Pennant Rock	? Etruria Marl Group
New Rock and Vobster Series	Blackband Group

A comparison with the Kent Coalfield lends support to this suggestion. At the Tower Brickworks Boring the beds between 1,768 and 1,980 feet were provisionally referred by Kidston[1] to the Etruria Marl Group, while at Waldershare the Newcastle-under-Lyme Group is at 1,845 feet.

THE NEW ROCK AND VOBSTER SERIES

The New Rock and Vobster Series were referred by Kidston[2] to the Transition (= Staffordian Series), and were shown by the writer[3] to belong to the Blackband Group of that Series. An analysis of the plant remains obtained by the Geological Survey[4] from borings in these rocks in the Northern Area confirms this conclusion. This is given below.

[1] Kidston, R., 'Summary of Progress for 1918' (*Mem. Geol. Surv.*), 1919, p. 49.

[2] Kidston, R., 'On the Fossil Flora of the South Wales Coalfield, and the Relationship of its Strata to the Somerset and Bristol Coalfield' *Trans. Roy. Soc. Edinb.*, vol. xxxvii, pt. iii, no. 26, pp. 557-558.

[3] Crookall, R., 1925, *op. cit.*, p. 403.

[4] Cantrill, T. C., and B. Smith, 1919, *op. cit.*, p. 53, and Pringle, J., 1921, *op. cit.*, p. 92.

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ANALYSIS OF ZONAL SPECIES

Species recorded	General Distribution in Coal Measures		
	Radstockian	Staffordian	Yorkian
PTERIDOSPERMEAE AND FILICALES			
Alethopteris lonchitica (*Schloth.*)	? absent	very rare	very common
Asterotheca miltoni (*Artis*) ...	? absent	? very rare	very common
Corynepteris coralloides (*Gutb.*) ...	absent	very rare	fairly common
Linopteris obliqua (*Bunb.*) ...	absent	fairly rare	fairly common
Lonchopteris bricei *Brongt.* ...	absent	absent	fairly rare
Neuropteris heterophylla *Brongt.*	very rare	very rare	very common
,, tenuifolia *Schloth.* ...	absent	very rare	very common
Sphenopteris striata *Gothan* ...	absent	very rare	fairly common
,, ? trifoliolata (*Artis*)	absent	very rare	fairly common
EQUISETALES			
Calamites cisti *Brongt.*	very rare	vary rare	fairly common
Annularia microphylla *Sauveur* ...	absent	very rare	vary rare
SPHENOPHYLLALES			
Sphenophyllum cuneifolium (*Sternb.*)	absent	very rare	fairly common
LYCOPODIALES			
Sigillaria mammillaris *Brongt.* ...	absent	very rare	very common
CORDAITALES			
Cordaites principalis (*Germar*) ...	absent	fairly rare	very common

With the exception of *Linopteris obliqua*, *Lonchopteris bricei*, *Neuropteris tenuifolia*, *Sphenopteris striata*, *Calamites cisti*, and *Annularia microphylla*, all the above named plants have been recorded by the writer[1] from the New Rock and Vobster Series of this coalfield, where, however, they are of rare occurrence. They have all been recorded previously from the Staffordian Series (except *Annularia microphylla*) and are commoner in the Yorkian Series. There is a marked absence of Radstockian forms, but, while Yorkian species form the bulk of the flora, the typical rich Yorkian assemblage is not recognised. Many common Yorkian species of *Sigillaria*, *Sphenopteris*, *Neuropteris*, etc., are unrecorded, and those

[1] Crookall, R., *op. cit.*, 1925, p. 401.

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Yorkian plants which are present are all rare. This entirely confirms the previous reference of the beds to the lowest group of the Staffordian Series—the Blackband Group.

THE UPPER BEDS OF THE 'MILLSTONE GRIT'

Prior to 1925[1] there were no satisfactory records of plants from the 'Millstone Grit' of the Bristol and Somerset Coalfield. On the basis of the fossil flora obtained, however, it was possible to provisionally refer these beds to the Yorkian Series, an horizon which had hitherto been unrecognised in the coalfield. The above additional records[2] from these beds put the matter beyond doubt. All the plants listed, with the exception of *Stigmaria ficoides*, which has no specific or stratigraphical value, are typical of the Yorkian Series. No Radstockian species has been found in these rocks, while, though the total number of species occurring is comparatively small, several of the Yorkian plants are extremely common. The upper portion of the Millstone Grit to the north of Bristol must be referred to the Yorkian Series.

VI. CONCLUSIONS

The percentages of zonal plants occurring in each Series of the coalfield is given below:—

	Radstockian Species	Yorkian Species
Radstock Series	60	14
Farrington Series	42	28
New Rock and Vobster Series	18	56
Upper beds of 'Millstone Grit'	0	72

It will be seen that 70–75 per cent. of the species is diagnostic, the remainder being composed of non-zonal forms. There is a constant decrease in Radstockian and increase in Yorkian plants as the rocks are descended. These percentages, however, do not give an even approximately true indication of the stratigraphical value of the floras, as the frequency of the individual species is not taken into account. In the Radstock Series, for instance, probably 99 per cent. of the fossils are represented by examples of species of *Pecopteris*, together with *Alethopteris serli* and *Cordaites angulosostriatus*, while the Yorkian plants, though numbering 14 per cent. of the species-flora are invariably very rare, and most of the records are represented by a single specimen.

[1] Crookall, R., *op. cit.*, 1925, p. 403.
[2] See p. 72.

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The results obtained are summarised in Tables I and II, given below, as well as on Figs. 1 and 2, while Table III shows a comparison of the coalfield with neighbouring areas.

THE BRISTOL AND SOMERSET COALFIELD

TABLE I

	NORTHERN AREA		CENTRAL AREA (Pensford and Bromley)	SOUTHERN AREA (Around Radstock S. of Farmborough Fault)
	North of Bristol	Around Bristol (Kingswood)		
RADSTOCK SERIES	absent	absent	absent	present—Radstock Group of the Radstockian Series
FARRINGTON SERIES	present—Newcastle Group of the Staffordian Series	absent	present—Newcastle Group of Staffordian Series	present—Keele Group of the Radstockian Series
PENNANT ROCK	present—Staffordian Series	present—Staffordian Series	present—(presumably) Staffordian Series	present—(presumably) Staffordian Series
NEW ROCK AND VOBSTER SERIES	present—Blackband Group of the Staffordian Series	present—Blackband Group of the Staffordian Series	(presumably) present—(presumably) Blackband Group of the Staffordian Series	present—Blackband Group of the Staffordian Series
(upper) 'MILLSTONE GRIT'	present—Yorkian Series	present—(presumably) Yorkian Series	(presumably) present—(presumably) Yorkian Series	present—(presumably) Yorkian Series
(lower)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)	Lower Carboniferous (Vaughan)

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TABLE II

SERIES	GROUP	NORTHERN OR GLOUCESTER-SHIRE AREA	CENTRAL OR PENSFORD AREA	SOUTHERN OR RADSTOCK AREA
RADSTOCKIAN SERIES	Radstock Group	absent	absent	Radstock Series
	Keele Group	absent	absent	Farrington Series
STAFFORDIAN SERIES	Newcastle-under-Lyme Group	Farrington Series	Farrington Series	? absent
	? Etruria Marl Group	Pennant Rock	Pennant Rock	Pennant Rock
	Blackband Group	New Rock and Vobster Series[1]	(presumably) New Rock and Vobster Series	New Rock and Vobster Series
YORKIAN SERIES	—	Upper Beds of 'Millstone Grit'	(presumably) Upper Beds of 'Millstone Grit'	(presumably) Upper Beds of 'Millstone Grit'
LANARKIAN SERIES	—	absent	absent	absent
LOWER CARBONI-FEROUS	—	Lower Beds of 'Millstone Grit' (Vaughan)		

[1] In the Bristol district proper (*i.e.*, at Hanham, South Liberty Colliery, and at Deep and Speedwell Pits) the New Rock and Vobster Series are the highest coals worked. Hanham pit is now closed.

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TABLE III

Series	Group	Bristol and Somerset Coalfield	Kent Coalfield	Forest of Dean Coalfield	South Wales Coalfield
RADSTOCKIAN	Radstock	present	absent	absent	?
	Keele	present	present	present	present
STAFFORDIAN	Newcastle	present	present	present	present
	Etruria Marl	? present	present	absent ?	present
	Blackband	present	? present	absent	present
YORKIAN	—	present	present	absent	present
LANARKIAN	—	absent	absent	absent	absent ?

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FIG. 1.—*Geological Map of the Bristol and Somerset Coalfield* showing geographical and palaeobotanical divisions (based on map published by J. McMurtrie, *Trans. Inst. Min. Eng.*, vol. xx, 1901, p. 334). Scale: 1·7 miles to 1 inch.

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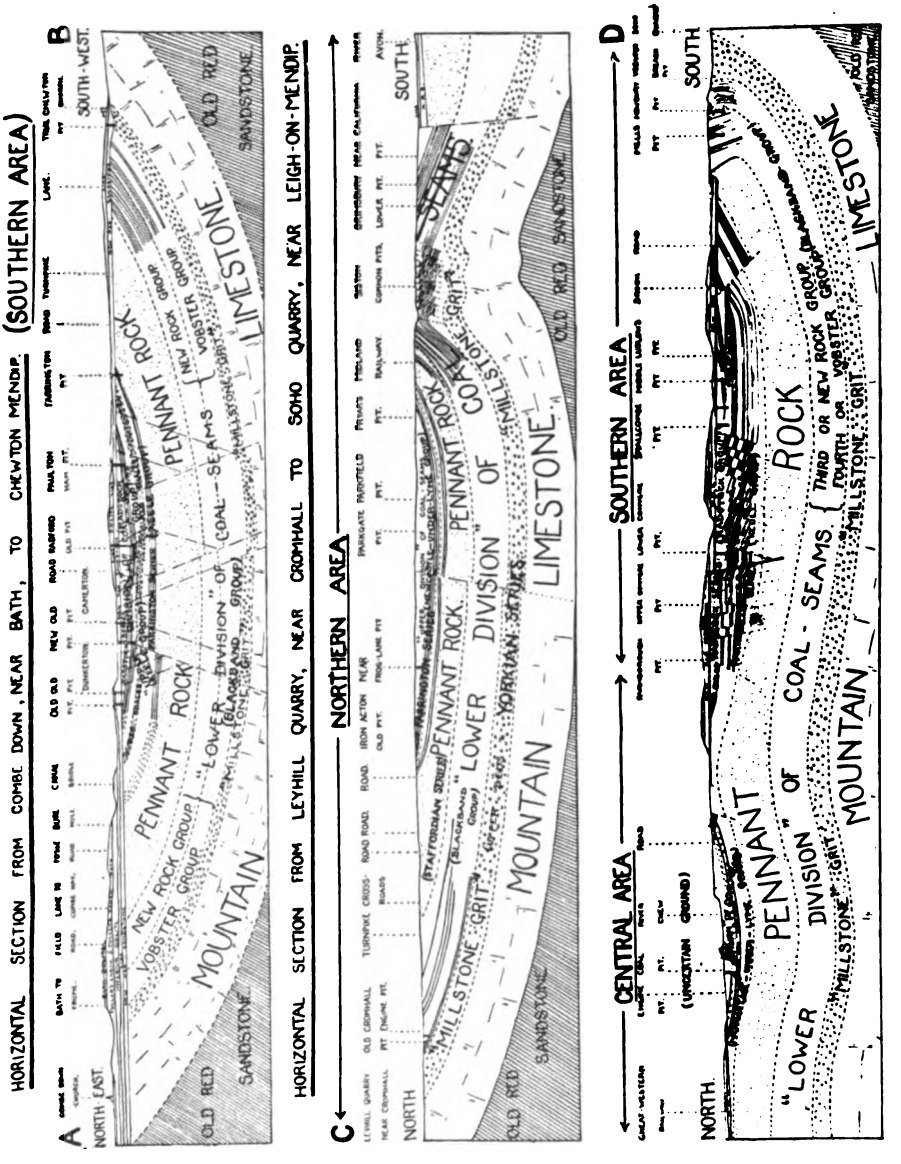

FIG. 2.—*Horizontal Sections from Combe Down, near Bath, to Chewton Mendip and Leyhill Quarry, near Cromhall to Soho Quarry, near Leigh-on-Mendip.*]

showing geographical and palaeobotanical divisions

(based on section published by J. McMurtrie, *Trans. Inst. Min. Eng.*, vol. xx, 1901, p. 334). Horizontal Scale: ·4 mile to 1 inch. Vertical Scale: 2,000 feet to 1 inch.

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VI.—On the Fossil Xiphosura from the South Wales Coalfield with a note on the myriapod *Euphoberia*.

By Emily Dix, M.Sc., and John Pringle, F.G.S.

Text-figures 1 to 16

Introduction

Fossil remains of Xiphosura are rare in the Coal Measures, and few specimens have hitherto been recorded from the rocks of the South Wales Coalfield. A number of examples of the genera *Belinurus*, *Prestwichianella* and *Euproops*, however, have been collected by the writers of this paper; some of the specimens are exhibited in the collections of the Museum of Practical Geology, London, while, in addition to those preserved at the University College, Swansea, others from the David Davies collection in the National Museum of Wales, Cardiff, and in the University College, Cardiff, have been lent to us by Dr. F. J. North and Prof. A. H. Cox, for the purpose of description and comparison.

The fossil Xiphosura at present known from the South Wales Coalfield are, with the exception of one specimen, preserved as impressions. They usually occur in well-laminated shale with other arthropods and plants, but occasionally fresh-water shells are also found associated with them. In all cases only the dorsal surface of the animal is preserved.

In some other coalfields, *e.g.*, Nottinghamshire, Derbyshire and Shropshire, the remains of Xiphosura appear to be more numerous, and are usually preserved in ironstone nodules. In the course of our studies, we have been able to examine a number of well-preserved specimens from English localities, and to use them for comparison with the material from South Wales. For these opportunities, we have to thank the Curators in charge of the collections in the Museum of Practical Geology and the British Museum (Natural History).

This paper deals with the occurrence of all the known specimens of Xiphosura from the South Wales Coalfield. Special attention has been given to the stratigraphical distribution of these genera and species, and it is of interest to note from the material we have studied that they appear to be found at horizons which can be traced over a fairly extensive area. Regarding the vertical range of these forms an interesting fact emerges from our studies, namely, that *Belinurus*, *Prestwichianella* and *Euproops* have not been found together in South Wales, as happens in the English Coalfields. One specimen of *Euproops* is recorded from a horizon in the *Carbonicola ovalis* Zone. Species of *Belinurus* have been noted in the Measures from the Gwendraeth Seam up to the Cwmgorse Marine Beds. Above this level, *Prestwichianella* appears and ranges

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up to the Mynyddislwyn Vein. *Euproops* reappears in fair abundance near the top of the Pennant Series and in the measures from the Three Feet to the Mynyddislwyn seams (see Table, p. 114).

We wish to express our sincere thanks to Dr. A. E. Trueman for his helpful criticism of this paper during preparation.

History of the Genera

The name *Belinurus* was applied by König[1] in 1820 to a small Limulid found in an ironstone nodule from the Coal Measures of Coalbrookdale in Shropshire. The genotype *Belinurus bellulus*, however, was not described until 1836, when Buckland[2] figured the species from this classical locality as *Limulus trilobitoides*, a name used by Prestwich, Portlock and others. In 1854, Pictet[3] revived König's genus, and Baily[4] working independently, employed the name in describing two new species in 1863.

Until 1866, all the Coal Measure Xiphosura were placed in the genus *Belinurus*, but in that year Woodward,[5] after a study of the species, concluded that they were readily divisible into two well-marked genera :—

(i) Forms with moveable thoracic segments and anchylosed abdominal ones. To this group he restricted the genus *Belinurus* with the species *B. bellulus*, *B. reginae* and *B. arcuatus*.

(ii) Forms with both thoracic and abdominal segments anchylosed and undivided. For these he established a genus which he named *Prestwichia* with *P. rotundata* as genotype and *P. anthrax* as another species.

In 1865, Meek and Worthen[6] had described a Coal Measure Xiphosurid under the name of *Belinurus danae*; later, Meek[7] transferred this species to a new genus, *Euproops*, in which he placed forms more or less intermediate in some characters between *Belinurus* and *Prestwichia*. *Euproops* agrees with *Prestwichia* in having the segments of the thoracetron (thorax and abdomen) fused, but differs from it in the quadrangular forms of the glabella and the position of the eyes, these being situated more anteriorly than in *Prestwichia*. Thus while Meek recognised three genera of Carboniferous Xiphosura, Woodward was only prepared to accept two.

[1] König, C., Icones Fossilium Sectiles, pl. 18, fig. 230.

[2] Buckland, W., Bridgewater Treatise, vol. i, p. 396, vol. 2, 1836, pp. 77.

[3] Pictet, F. J., Traité de Paléontologie, Qd. ed., vol. 2, p. 538.

[4] Baily, W. H., 'Remarks on some Coal-measure Crustacea belonging to the genus *Belinurus*, König,' etc., *Ann. Mag. Nat. Hist.*, 3d ser., 11, pp. 107-114, 1863.

[5] Woodward, H., 'On some Points in the Structure of the Xiphosura, having reference to their relationship with the Eurypteridae,' *Quart. Journ. Geol. Soc.*, 1867, pp. 23, 31-33.

[6] Meek, F. B., and A. H. Worthen, March, 1865, *Proc. Acad. Philad.*; *Geol. Reports Illinois*, vol. ii, 1866, p. 365.

[7] Meek, F. B., *Amer. Journ. Sci. and Arts*, May, 1867. See also 'Notes on a New Genus of Fossil Crustacea,' *Geol. Mag.*, 1867, p. 230, and Meek, F. B., and A. H. Worthen, *Survey of Illinois* (*Palaeontology*), vol. iii, 1868.

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Before 1918, however, Woodward[1] came to the conclusion that *P. anthrax* and *P. rotundata* were generically distinct, and he placed the first-named with *Euproops*, and the name *Prestwichia* having been previously used as a genus of Hymenoptera by Lubbock in 1863, he proposed the name *Prestwichianella* for those forms which are allied to the genotype *P. rotundata*.

Belinurus

Diagnosis.—Body limuloid, head-shield or prosoma semi-circular with long genal spines from the posterior angles. Median part of prosoma (glabella) prominent and divided into two lobes, declining towards the circumference and surrounded by a narrow flattened margin. Mesosoma, consisting of five free segments, each produced laterally into spines. Metasoma small, formed of three fused segments, and a long telson. Geno-holotype, *B. bellulus* König.

Belinurus concinnus sp. nov.

Fig. 1.

This specimen was collected by Mr. W. D. Ware from shales associated with the Brass Vein at the Diamond Colliery, Ystradgynlais. The specimen consists of a fairly well-preserved head-shield and the greater portion of the thoracetron.

Dimensions.—

Length of prosoma, 11 mm.
Breadth of prosoma, 18 mm.
Length of glabella, 9 mm.
Length of prosoma and thoracetron, 17·5 mm.
Breadth of glabella, 6 mm.
Estimated breadth of thoracetron, 13 mm.
Breadth of axis of thoracetron, 3·5 mm.

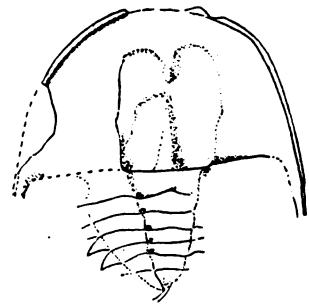

Fig. 1.—*Belinurus concinnus* sp. nov. (x 2).

The head-shield (prosoma) is nearly semi-circular in outline, the posterior portion being produced into genal spines of which only a

[1] Woodward, H., 'Notes on some Fossil Arthropods from the Carboniferous Rocks of the Cape Breton, Nova Scotia,' etc., *Geol. Mag.* vol. lv, 1918, p. 468.

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portion of one is preserved. This genal spine projects downwards and is almost parallel to the thoracetron. Around the prosoma, the posterior margin of which is nearly straight, is a well-defined flattened border about one millimetre in width. The glabella is well shown, and in size is large in relation to the prosoma. The ophthalmic lines are marked; two lateral eyes, and also the position of a third median eye is indicated on the ridge, which divides the glabella into two lobes.

The thoracetron is distinctly trilobed. It is imperfectly preserved, but six free thoracic segments can be seen. Each segment is terminated by a short blunt spine. The axis of the thoracetron is of the same width as that of the posterior margin of the glabella, which measures 5 mm., but diminishes to 3·75 mm. near the telson. There is a small coalesced caudal portion bearing a tubercle above the point of insertion of the telson. The latter is about 1 mm. in breadth, but since it is only imperfectly preserved, its exact length cannot be ascertained. We have named this species *Belinurus concinnus*.

The long head-shield, which is more than half the length of the animal (minus the telson) serves to distinguish *B. concinnus* from other species. It shows some points of resemblance with *B. trechmanni* Woodward in the broad, almost parallel side axis of the thoracetron, and also in the presence of six free segments. Our specimen differs from this species in possessing posteriorly projecting genal spines, and in the marked difference in the shape of the head-shield. In *B. trechmanni* Woodward, the glabella is about two-thirds the length of the cephalon; in *B. concinnus* it is longer.

The holotype of this species is preserved in the Museum of Practical Geology, London, and is registered 48775.

B. carwayensis sp. nov.

Fig. 2.

In some blue shale from the roof of a thin seam above the Hwch Vein at Carway Colliery, Carmarthenshire, an almost complete specimen of *Belinurus* was collected.[1] Associated with it were shell fragments, chiefly those of *Naiadites*, and plant remains, including *Lepidophyllum sp.*

Dimensions.—

Length of prosoma, 8 mm.
Breadth of prosoma, 15·5 mm.
Length of thoracetron, 5·5 mm.
Breadth of thoracetron at posterior margin of prosoma, 11 mm.
Length of glabella, 4·5 mm.
Breadth of glabella, 4 mm.
Estimated length of genal spine, 5 mm.
Breadth of axis of thoracetron, 3 mm.
Breadth of anterior thoracic segment, 2·5 mm.
Length of longest thoracic spine, 1·75 mm.

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and Adjoining Areas,' *Proc. South Wales Inst. Eng.*, vol. xliv, No. 5, 1928, p. 479.

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The prosoma is semi-circular in outline, with the posterior angles extended into fairly long genal spines. These spines make an angle of about 100 degrees with the posterior margin of the prosoma which is almost straight. The glabella is not well-preserved, but the two lobes and one of the lateral eyes can be distinguished. The posterior margin of the head-shield measures 16 mm. in breadth across the genal spines. The mesosoma is much narrower, distinctly trilobed, and is more or less semi-circular in outline. It is composed of five free segments diminishing in breadth from the anterior backwards. Each of the segments is terminated on either margin by a stout slightly recurved spine. The metasoma is small, with two segments terminated as spines. The telson is not preserved.

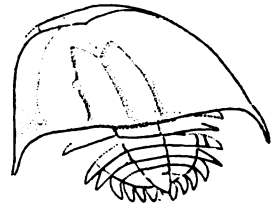

FIG. 2.—*Belinurus carwayensis* sp. nov. (x $1\frac{5}{6}$).

In the characters of the prosoma *B. carwayensis*. resembles *B. trechmanni* Woodward. It agrees with that species in general shape although the head-shield in the specimen from Carway is much bigger in proportion to the thoracetron, while the angle between the genal spine and the posterior margin of the prosoma is similar in the two species. *B. carwayensis*, however, differs from *B. trechmanni* in other characters and resembles *B. bellulus* König, *B. arcuatus* Baily and *B. baldwini* Woodward in having a narrower thoracetron in comparison with the posterior margin of the cephalon. The central axis of the thoracetron of our species is well defined and it agrees with *B. bellulus* Woodward and *B. arcuatus* Baily in being narrower than the width of the glabella. No tubercles are seen on the segments of the thoracetron.

The specimen taken as holotype has been presented to the Geological Department, National Museum of Wales (No. 29,197, G 3.).

Belinurus truemani sp. nov.

Fig. 3.

A small Belinurid was found in blue shale at a depth of 1,280 feet (about 260 feet below the Red Vein), in a borehole at Cwmgorse.[1]

[1] Davies, D. F., E. Dix, and A. E. Trueman, 'Boreholes in Cwmgorse Valley,' *Proc. South Wales Inst., Eng.*, vol. xliv, p. 37.

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Dimensions.—

Breadth of prosoma, 6 mm.
Length of prosoma, 2·5 mm.
Length of prosoma and thoracetron, 4·5 mm.
Length of glabella, 2 mm.
Breadth of glabella, 3 mm.
Length of genal spine, 2 mm.
Breadth of thoracetron at the anterior margin, 3·5 mm.

In general form it is broadly ovate, with a convex axis. The prosoma is nearly three times as broad as long, and is more or less oval in outline. The glabella is well-marked by three grooves, the central one being broadest and dividing the glabella into two lobes. The two outer grooves mark the ophthalmic lines on which are seen the impressions of the two lateral eyes, situated near the anterior margin. The ophthalmic ridges are produced into short neck spines about 2 mm. in length.

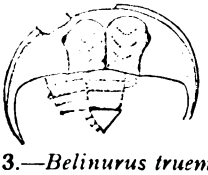

FIG. 3.—*Belinurus truemani* sp. nov. (x 4).

The glabella is large in relation to the prosoma and extends almost to the anterior edge of the prosoma. The cephalic shield is surrounded by a narrow flattened margin, the posterior angles being projected into long incurved genal spines.

The mesosoma is small, distinctly trilobed, and composed of four free segments which are terminated in blunt spines. The metasoma, which is well marked, is roughly triangular in shape and is apparently made up of three fused segments ; there are three spines on each side of the caudal area. The telson is missing, so that it is impossible to state the length it attained.

Belinurus truemani differs from all known species of *Belinurus* in the shape of the cephalon, the forward position of the eyes, the long incurved genal spines, in having only four free segments in the mesosoma and in the peculiar caudal area.

The holotype of this species has been presented to the Geological Department, National Museum of Wales (No. 29,197, G.1.).

Belinurus pustulosus sp. nov.

Fig. 4.

An interesting fragment of a Xiphosurid representing the greater portion of a head-shield was found in grey shale from the roof of the Stanllyd Seam at the Carway Colliery, Carmarthenshire.[1] The

[1] Dix, Emily, 'The Coal Measures of the Gwendraeth Valley and Adjoining Areas,' *Proc. South Wales Inst., Eng.*, vol. xliv, no. 5, p. 480.

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specimen shows a negative impression only, but in the following description the details given are those of the positive.

Dimensions.—

Estimated breadth of prosoma, 30 mm.
Length of prosoma, 12 mm.
Length of glabella, 9 mm.
Breadth of glabella lobes near orbits, 4 mm.

The prosoma is more than twice as broad as long. The front margin is gently curved, and the posterior margin is practically straight. The head-shield is surrounded by a narrow raised rim, which is well shown around the genal spines and the posterior margin. Outside this rim is a narrow flattened area. The genal spines are moderately long, making an angle of about 120 degrees with the posterior margin of the prosoma. The glabella in this specimen is well preserved. The ophthalmic ridges are prominent, and slightly curved in the region of the orbits; one of the lateral eyes is well shown.

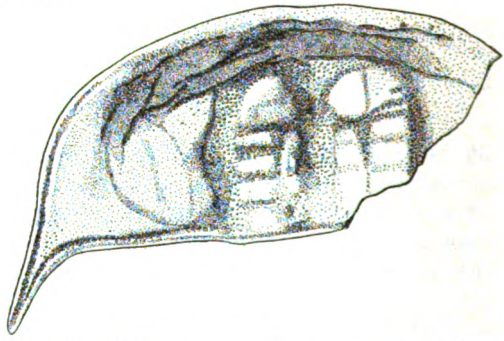

FIG. 4.—*Belinurus pustulosus* sp. nov. (x $2\frac{2}{3}$).

The characteristic feature of this specimen, however, is the segmentation of the glabella, which shows traces of five or possibly six segments. The glabella is divided along the middle line into two well-defined lobes, each being again divided by a longitudinal ridge which extends for about two-thirds of its length. In this posterior portion of the glabella are three well-marked segments and a feeble fourth posterior segment; in the anterior part of the glabella, which forms a depressed area, are traces of two feebly marked segments.

A fine pitting, indicating the pustulose character of the ornament, is seen where the surface of the head-shield is well preserved, particularly along the genal spine, the ophthalmic ridges and the ridges of the glabella.

Outside the lateral margins of the glabella is a shallow, slightly depressed area bounded by a distinct curved line.

This specimen differs from other species of *Belinurus* in having distinct segmentation of the glabella, in which character it resembles

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Paleolimulus avitus of Dunbar[1]. The pattern of the glabella in *Belinurus pustulosus* is markedly different from that of *P. avitus*. Segmentation of the glabella is also known to occur in a species of *Euproops*, namely *E. amiae* Woodward.

Other features which serve to distinguish our specimen from other species of *Belinurus* are the depressed anterior portion of the glabella, the pustulose ornament of the head-shield, and the distinct raised border of the head-shield.

As our specimen is incomplete there is some doubt as to its true affinity, but from the characters available it appears to be more closely allied to *Belinurus* than to any other existing genus. It may possibly represent a new genus intermediate in characters between *Belinurus* and *Paleolimulus*.

The specimen, the holotype of the species, has been presented to the National Museum of Wales, and is registered 29,197, G2.

Belinurus bellulus König

Fig. 5.

A well-preserved specimen of *Belinurus* was found in some blue shale from the roof of the Gwendraeth Vein at the Glyn-Hebog Colliery, Carmarthenshire.[2] It consists of an almost complete prosoma, and the three anterior segments of the mesosoma. The specimen agrees in all its characters with *B. bellulus*, and we refer it without any hesitation to König's species.

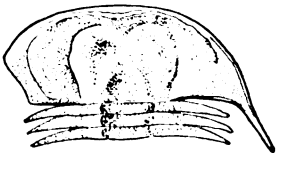

FIG. 5.—*Belinurus bellulus* König (x 2¾).

At this locality *B. bellulus* is associated with fresh-water shells, including *Naiadites modiolaris* (J. de C. Sow.), and fragments of plants. Another fragment of *Belinurus* was found, but it is too small to permit the identification of the species to which it belongs.

Our specimens are now in the collection of the University College of Swansea.

Belinurus sp. (? *B.* cf. *bellulus* König.)

A portion of the prosoma of a Belinurid was collected from some dull grey shale passed through at a depth of 1,271 feet, about 251 feet below the Red Vein, in No. 1 Borehole at Cwmgorse.[3]

[1] Dunbar, Carl O., 'Kansas Permian Insects.' Part 2. *Paleolimulus*, etc. *The American Journal of Science*, vol. v, 1923, p. 443.
[2] Dix., E., *ibid.*, p. 463.
[3] Davies, D. F., E. Dix and A. E. Trueman, *ibid.*, p. 37.

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The prosoma has a narrow flattened margin, and has two fairly long genal spines. A portion of the glabella is preserved, showing two lobes. The exact identification of the specimen, however, is impossible owing to its fragmentary nature, but the characters of the prosoma suggest affinities with *B. bellulus* König.

Belinurus arcuatus Baily

Fig. 6.

This specimen was collected from some dark blue shale from the roof of the Rock Vein, Blaina Colliery, Pantyffynon. Associated with it were fragments of the shells of *Anthracomya* and plant fragments, including *Calamites sp.*

The specimen shows an almost complete prosoma together with two segments of the mesosoma. Other segments of the thoracetron are possibly preserved underneath the prosoma, thus giving rise to the ridges seen on the lateral areas of the head-shield.

Dimensions.—

Length of prosoma, 7 mm.
Breadth of prosoma across genal spines, 13 mm.
Length of glabella, 5·1 mm.
Breadth of glabella, 4 mm.
Length of genal spine, 3·5 mm.
Breadth of thoracetron, 7 mm.
Breadth of axis of thoracetron, 2·25 mm.

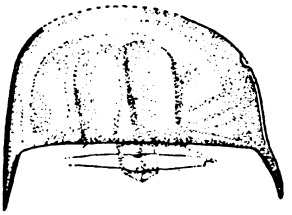

FIG. 6.—*Belinurus arcuatus* Baily (x 2¾).

The prosoma is semi-circular in outline, slightly elevated, and surrounded by a narrow flattened margin. The posterior angles of the prosoma are produced into long genal spines making an angle with the posterior border of the cephalon comparable with that of the type of the species. In our specimen from Pantyffynon the glabella is well-marked and is a little over two-thirds the length of the prosoma as in the type of *B. arcuatus*. The ophthalmic ridges are slightly curved showing the position of the two lateral eyes, and one of the ridges appears to be produced to form a short neck spine. The width of the thoracetron is small in comparison with that of the prosoma as in *B. bellulus*; the central axis also is narrow, one of the characteristic features of this species.

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The Pantyffynon specimen is closely similar in many characters to *B. arcuatus* Baily, and although the prosoma is slightly longer than in the type species, a difference which may be due to preservation, we have no hesitation in referring it to *B. arcuatus*.

The specimen is preserved in the collection of the University College of Swansea.

Belinurus cf. *arcuatus* Baily

Fig. 7.

A well-preserved head-shield of a Belinurid was collected by Mr. W. D. Ware from the roof shales of the Brass Vein at the Diamond Colliery, Ystradgynlais. The dimensions of this specimen are as follows :—

Length of prosoma, 6·5 mm.
Breadth of prosoma across genal spines, 13 mm.
Length of glabella, 4 mm.
Breadth of glabella (near eyes), 4·5 mm.
Length of genal spine, 4 mm.
Length of neck spine, 1·25 mm.

The prosoma is semi-circular in shape, with the anterior margin gently curved ; it is slightly elevated, declining towards the circumference, and surrounded by a narrow flattened margin. The glabella is well-defined and divided into two lobes ; the ophthalmic ridges are slightly curved, showing the position of two lateral eyes. These ridges are continued across the posterior margin of the head-shield and form neck spines about 1½ mm. in length. The posterior margin of the cephalon, on either side of the glabella, slopes anteriorly. The genal spines are long, making an angle of about 95 degrees with the posterior margin of the head-shield.

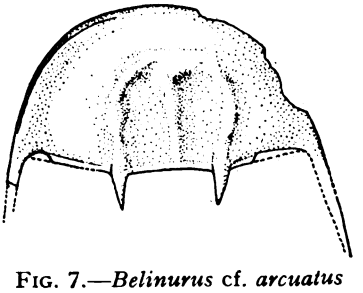

FIG. 7.—*Belinurus* cf. *arcuatus* Baily (x 3½).

In shape, the prosoma is more orbicular than that of *B. reginae* Baily or of *B. bellulus* König, and it also differs from these species in the presence of two neck spines, similar to those seen in *B. arcuatus* Baily. It is distinguished from the last mentioned species, however, in the gently curved anterior margin of the prosoma, and further, the posterior margin, which is straight in *B. arcuatus* Baily, slopes anteriorly on either side of the glabella in our specimen.

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Apart from these minor differences, we think our example from Ystradgynlais is closely allied to Baily's species, and until additional material is available for study, we suggest that it be compared with *B. arcuatus*.

The specimen is preserved in the collections of the Museum of Practical Geology, Reg. No. 48774.

Belinurus cf. *kōnigianus* Woodward

Fig. 8.

A Belinurid closely resembling *B. konigianus* Woodward was obtained from a bed of shale at a depth of 1,466 feet in No. 1 borehole at Cwmgorse.[1] The horizon is about 454 feet below the Red Vein, in

FIG. 8.—*Belinurus* cf. *kōnigianus* Woodw. (x 2).

the zone of *Anthracomya pulchra*. Unfortunately, only the prosoma is preserved, but as will be seen from the figure, the characters of the head-shield are almost identical with those of *B. kōnigianus* Woodward.

Belinurus sp. (? *B. reginae* Baily)

Associated with fragments of fresh-water shells, a fragment of a Belinurid was collected by Dr. A. E. Trueman from dark blue shale from the roof of the Brynlloi Seam at the Pontyclerc Colliery, Pantyffynon, Carmarthenshire. Only five free thoracic segments and an anchylosed caudal portion are preserved. The mesosoma shows the typical trilobed appearance and the central axis is well-marked. The free segments terminate in blunt slightly curved spines. On four of the free segments a small tubercle is seen, similar to those found in *B. reginae* Baily.

Belinurus sp.

This specimen was found in blue shale forming the roof of the Brasslyd Seam at the Pentre Mawr Colliery, Carmarthenshire[2]. It consists of an incomplete cephalic shield on which the glabella with the ophthalmic ridges and lateral eyes are well shown, but the other portion is so poorly preserved that specific identification is impossible.

[1] Davies, D. F., E. Dix and A. E. Trueman, *ibid.*, p. 37.
[2] Dix, E., *ibid.*, p. 465.

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PRESTWICHIANELLA 1918=PRESTWICHIA

Diagnosis :—Prosoma semicircular, continued into spines at the posterior angles ; median raised part (glabella) broad, divided along the centre by the axial furrow, and by two other slightly diverging parallel lines on either side of the axis, reaching nearly half-way to the frontal border, where they are arcaded, forming a rounded raised confluent line in front of the glabella. The circular line seen outside the border of the glabella may indicate the impression of the line of the broad incurved under-margin of the head-shield.[1] Compound eyes are situated on the anterior lateral angles of the glabella. The thoracic abdominal segments, usually seven, are fused together to form a shield, with a flat marginal part produced into short spines and a long tail spine. The central axis of the body segments is narrow.

Prestwichianella nitida sp. nov.

Fig. 9.

The highly fossiliferous grey shales from the roof of the Graigola Seam yielded an abundant flora and fauna at the Clydach Merthyr Colliery, and the remains of arthropods were also particularly abundant : these included *Euphoberia sp.*, *Orthomylacris lanceolata* Bolton, *Hemimylacris sp.*, *Euproops graigolae* sp. nov., and the new species of *Prestwichianella* described below.

Dimensions.—

Estimated length of prosoma, 14 mm.
Estimated breath of prosoma, 28·5 mm.
Length of glabella, 11 mm.
Breadth of glabella lobes near the eyes, 13 mm.
Breadth of glabella lobes at posterior margin, 9·5 mm.
Length of mesosoma (preserved), 8 mm.
Estimated breadth of thoracetron, 23 mm.
Breadth of marginal fringe, 3·25 mm.
Breadth of central axis of thoracetron, 3·25 mm.

The prosoma, which is incomplete, is probably more than twice as broad as long, and is nearly semicircular in outline. Only a fragment of one of the genal spines is preserved, but this gives some indication of the proportions of the prosoma. The glabella is quadrangular in outline, and is slightly raised. The eyes appear to be placed on the anterior lateral angles but they are not well shown. A portion of the glabella is divided into two lobes by means of a narrow raised ridge, which broadens and becomes flattened at the posterior margin.

About 3 millimetres from the anterior margin of the glabella lobes two ridges are developed at right angles to the median ridge (of the glabella) ; these ridges are about two millimetres in length

[1] Woodward, H., ' Notes on some Fossil Arthropods from the Carboniferous Rocks of Cape Breton, Nova Scotia,' etc., *Geol. Mag.*, vol. 55, p. 469, 1918.

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and they diverge gradually beyond the median ridge to join the lateral posterior margin of the glabella. On either side of the lateral margins of the glabella lobes are two faint curved lines, which appear to join the posterior margin of the prosoma, and a curved line outside these lobes can also be seen on the specimen. One lateral margin of the glabella lobe appears to be produced into a short neck spine.

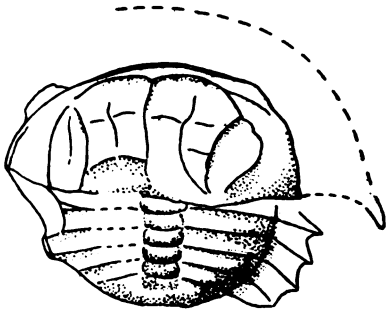

FIG. 9.—*Prestwichianella nitida* sp. nov. (x 2).

The thoracetron, which articulates along the anterior margin of the prosoma, is about three times as broad as long. The mesosoma is distinctly trilobed and consists of six coalesced segments which decrease in length posteriorly. The ridges and furrows of each segment are marked on the narrow central axis, and they curve slightly backwards. Each segment terminates in a prominent marginal spine; the spines are united to each other by a broad membrane, beyond which they slightly project. The third segment from the anterior margin of the thoracetron is ornamented with a large blunt tubercle.

Unfortunately the abdominal segments and the telson are not preserved.

Prestwichianella nitida differs from *P. rotundata* Prestwich in the characters of the head-shield. In *P. rotundata* the length of the glabella lobes is only about half that of the prosoma and also half the length of the thoracetron. In *P. nitida* the length of the glabella lobes is probably more near two-thirds that of the prosoma and is equal to the length of the thoracetron. The shape and character of the thoracetron are similar in both species, but the marginal fringe in *P. nitida* is wider than in *P. rotundata* and the spines are shorter.

The specimen taken as holotype is preserved in the collections of the Museum of Practical Geology, Reg. No. 48532.

Prestwichianella rotundata (Prestwich)

We have not been able definitely to recognise the presence of this well-known species of *Prestwichianella* in the South Wales Coalfield, although specimens from four localities show affinities close enough

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to suggest comparison with it. The difficulty has been mainly due to the fragmentary nature of our material.

One specimen from the roof-shales of the Hughes Vein at Kilvey Hill shows a portion of the prosoma attached to an almost complete thoracetron, and the latter strongly resembles that of Prestwich's species.

Another example from the roof of the Mynyddislwyn Vein, formerly worked at the Gelli-deg Level, Maesycwmmer, exhibits only a portion of the mesosomatic and metasomatic segments, but their characters strongly suggest affinities with *P. rotundata* Prestwich. The fragment had been previously identified as *P.* cf. *rotundata* by Mr. E. T. Newton, F.R.S.,[1] but we cannot give a definite determination on account of its incomplete state of preservation. This specimen and its counterpart are preserved in the collection of the Museum of Practical Geology, and are numbered 25423 and 48522 respectively.

Two specimens, collected by Mr. David Davies, one from the roof of the Six Feet Vein at the Cae Duke Colliery, near Swansea, and the other from the Upper Gelli Seam, Pontardulais, are preserved in the collections of the National Museum, Cardiff, and are registered as 27,177,G4 and 27,177,G5. The example from the Cae Duke Colliery consists of the thoracetron attached to a fragment of the prosoma. The central axis of the thoracetron is well shown, and each of the six fused segments bears a small tubercle; the seventh segment has a more prominent tubercle, as in the type of the species. In our specimen the marginal spines extend only a short distance beyond the fringe.

Prestwichianella sp.

A well-preserved thoracetron of *Prestwichianella*, now in the collections of the Welsh National Museum and numbered 27,177,G2, was found by Mr. D. Davies, F.G.S., in an ironstone nodule at the base of the Staffordian Series at Gilfach Goch. Six segments are shown, and each bears a tubercle on the central axis. A characteristic feature of this specimen is the broad marginal fringe of the thoracetron.

Until more details are obtained from additional material, we refer the specimen provisionally to the genus *Prestwichianella*.

EUPROOPS

Diagnosis: Prosoma semicircular, continued into genal spines which curve upwards and outwards from the posterior border of the head-shield. Median raised portion of the prosoma (glabella) is quadrangular, with the compound eyes situated on its anterior lateral angles. The mesosomatic and metasomatic segments, usually seven in number, are united together forming a shield, with a flat marginal part produced into spines, and a long tail spine.

[1] 'The Country around Merthyr Tydfil,' Pt. v (*Mem. Geol. Surv.*), 1904, p. 78.

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Euproops graigolae sp. nov.

Fig. 10.

This specimen was found associated with *Prestwichianella nitida* in shales from the roof of the Graigola Seam at the Clydach Merthyr Colliery (see p. 101). It is nearly complete, only a portion of the telson and the genal spines being not preserved.

Dimensions:—

Length of prosoma, 10 mm.
Breadth of prosoma across the genal spines, 20 mm.
Length of glabella, 6·5 mm.
Breadth of glabella between the eyes, 8·5 mm.
Breadth of glabella at the posterior margin of the prosoma, 6 mm.
Length of thoracetron, 11 mm.
Breadth of thoracetron including marginal fringe, 17·5 mm.
Breadth of marginal fringe, 3 mm.
Breadth of central axis, 3 mm.

The prosoma is almost semi-circular in shape, with the posterior angles produced into short genal spines. The frontal border is narrow and slightly flattened. The posterior margin curves slightly anteriorly to meet the lateral margins of the prosoma in the genal spines.

The glabella is well-preserved; it is 6 millimetres wide at the cervical border, and it widens to 8·5 millimetres across the line of the orbits. It forms a double arch in front, and is united in an acute V-shaped, posteriorly directed ridge in the central line; this ridge extends backwards to the posterior margin of the prosoma, dividing the glabella into two lobes. About 1 millimetre on either side of the median ridge, two other faint ridges are developed, and these extend anteriorly for about 3 millimetres, and then turn at right angles to join the median line. The lateral margins of the glabella are produced and form neck spines.

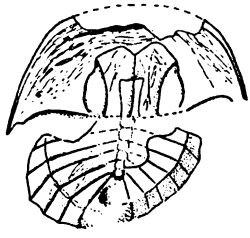

FIG. 10.—*Euproops graigolae* sp. nov. (x 1½).

The thoracetron articulates along its anterior border with the posterior margin of the prosoma. It is slightly elevated and is almost cordiform in shape. The thoracetron is distinctly trilobed and is made up of six equal segments. The specimen originally showed the central axis, which was very narrow, being less than 3 millimetres broad at the cervical border, and equal in width to the

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smaller lobes of the glabella; it decreases in width posteriorly to about 1½ millimetres. Unfortunately in dissecting out further details of the thoracetron a portion of the anterior segments and the central axis were destroyed. The segments are about 1½ millimetres wide and are terminated in well-marked spines, which are united together to form a marginal fringe. The extremities of the spines are not preserved in this specimen, but they probably extended some distance beyond the fringe.

The abdomen is poorly preserved and probably consists of two fused segments. The length of the telson is unknown.

Compared with the type of *Euproops* (*E. danae* Meek and Worthen) the prosoma of *E. graigolae* is longer from back to front; the glabella is smaller in proportion to the prosoma, but the angle which the genal spine makes with the posterior margin of the prosoma is closely similar to that of the genotype. The shape of the thoracetron in our specimen differs from *E. danae* Meek and Worthen and resembles that of *E. amiae* Woodward. The marginal fringe is well-developed in *E. graigolae*, but the extent of the spines beyond the fringe is unknown. The surface of the prosoma and the marginal fringe in *E. graigolae* appears to be striated.

The holotype of this species is preserved in the Museum of Practical Geology and is numbered 25424.

Euproops gwenti. sp. nov.

Fig. 11.

A good specimen of *Euproops* with its counterpart was collected from dark grey shale from the roof of the Mynyddislwyn Seam, Gellideg, Monmouth. Associated with it were a rich flora and other interesting fossils, including *Archimylacris sp.*, *Palaeoxyris* cf. *carbonaria* and *Diplodus gibbosus*.

Dimensions.—

Estimated length of prosoma, 16 mm.
Breadth of prosoma, 27·5 mm.
Length of glabella, 11 mm.
Breadth of glabella near orbits, 10 mm.
Breadth of glabella at posterior margin of prosoma, 8 mm.
Length of genal spine, 10 mm.
Length of thoracetron, 13 mm.
Breadth of thoracetron (minus fringe), 18 mm.
Breadth of central axis, 2·5 mm.
Breadth of marginal fringe (preserved), 1·5 mm.
Length of telson, unknown.

The characters of the head-shield of our specimen readily distinguish it from other species of *Euproops*. Unfortunately, a portion of the prosoma near the anterior margin is not preserved, but from the details available it may be concluded that the prosoma is probably semi-circular in shape. A well-defined flattened area is seen along the posterior margin of the prosoma, and is continued around the

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genal spines; it probably extended around the anterior margin of the prosoma. The posterior angles of the head-shield are produced into long genal spines. The central portion of the posterior margin of the prosoma (that is, in the region of the glabella) is straight, but on either side it slopes anteriorly forming an angle of about 95 degrees with the genal spines. In this character it is similar to *E. amiae* Woodward, and intermediate between *E. danae* Meek and Worthen and *E. anthrax* Woodward.

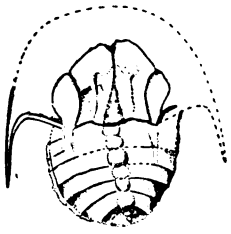

FIG. 11.—*Euproops gwenti* sp. nov. (nat. size).

The gabella is quadrangular and resembles that of *E. danae* and that of the specimen figured as *Prestwichia rotundata* Prestwich by Mr. G. C. Greenwell, F.G.S.[1] The glabella, which is slightly raised, is 11 millimetres in length, and 10 millimetres wide across the orbits. The lateral margins of the glabella curve inwards and then slightly outwards to join the posterior margin of the prosoma, where they are 9·5 millimetres apart; the lateral margins are produced and form short neck spines. The position of the eyes cannot be determined in our specimen. The glabella is divided for half its length by a narrow raised ridge. Between the posterior margin of this ridge and the cervical border, is an area about 2·5 millimetres wide which appears to be a prolongation of the axis of the thoracetron. Faint traces of grooves are seen on this area similar to *E. amiae*. The area between the glabella and the margin of the prosoma shows a pustulose ornament.

The coalesced mesosomatic and metasomatic segments form a heart-shaped shield. The mesosoma consists of six segments which are marked by ridges. The spines or extremities of the segments are joined together by a membrane, only a small portion of which is seen in the specimen. The axis of the thoracetron is narrow and each segment is ornamented with a tubercle. It is impossible to make out the number of segments in the metasoma, but the axis just above the insertion of the telson is ornamented with one large tubercle. The telson is not preserved.

In general shape, and in the characters of the glabella *E. gwenti* shows affinities to *E. danae*, but it differs from this species in the greater angle between the posterior margin of the prosoma and the

[1] Greenwell, G. C., 'On *Prestwichia* found in the Coal Measures of East Somersetshire,' *Trans. Manch. Geol. Soc.*, vol. vi, p. 123, 1866-7.

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anterior margin of the thoracetron, in which character it resembles *E. amiae.* It, however, differs from *E. amiae* in having a narrower axis to the thoracetron and also in the shape of the thoracetron. *E. gwenti* is readily distinguishable from other species of the genus by the pustulose character of the prosoma.

The holotype of this species and its counterpart are preserved in the Museum of Practical Geology, and are registered 48523, and 48524.

Euproops islwyni sp. nov.

Fig. 12.

This specimen, with a portion of its counterpart, was found in association with *E. gwenti* sp. nov., in grey shale from the roof of the Mynyddislwyn Seam, Gellideg, Monmouth. Two well-preserved fragments of the head-shield and a portion of the thoracetron are preserved. In the specimen numbered 48526 a portion of the prosoma is doubled under the thoracetron. The characters described are those of the positive.

Dimensions.—

Estimated length of prosoma, 16 mm.
Breadth of prosoma across genal spines, 34 mm.
Length of glabella, 9·5 mm.
Breadth of glabella between the orbits and at the cervical border, 12·5 mm.
Length of genal spine, 9·5 mm.

The prosoma is almost semicircular in shape and is surrounded by a narrow flattened border. The posterior margin of the prosoma slopes gently anteriorly on either side of the glabella, and meets the lateral margins in the genal spines. The prosoma most closely resembles that of *E. scheeleana* Ebert, in the angle which the posterior margin of the prosoma makes with the genal spine and also in the long, thin, slightly incurved genal spines as seen in one of Ebert's figures. It differs from this species, however, in the form and markings of the glabella.

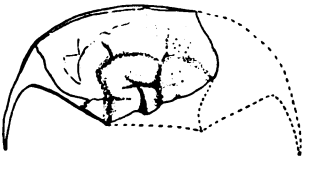

FIG. 12.—*Euproops islwyni* sp. nov. (nat. size).

The glabella is not quite so quadrangular as in other species of this genus. It is divided by a median ridge into two lobes, which are again partially divided into two more lobes at right angles to the median range. The position of the eyes cannot be determined owing to the state of preservation.

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Only a portion of five of the segments and the axis of the mesosoma are preserved. The segments are nearly 2 millimetres wide, and curve very slightly posteriorly. To this species we give the name *Euproops islwyni*.

The holotype of this species with its counterpart are preserved in the Museum of Practical Geology and are numbered 48526 and 48525 respectively.

Euproops meeki sp. nov.

Fig. 13.

A specimen of *Euproops* was collected from shales from the roof of the Mynyddislwyn Seam, at the Gwernau Level, three-quarters of a mile S.E. of Maesycwmmer. Unfortunately only the prosoma and its counterpart are preserved. It resembles the prosoma of *E. anthrax* Woodward, but there are important differences.

Dimensions.—

Length of prosoma, 13 mm.
Breadth of prosoma, 38 mm.
Length of glabella, 9·5 mm.
Estimated width of glabella, 20 mm.
Distance between neck spines, 10 mm.

The prosoma is almost elliptical in shape, with the frontal margin well marked as in *Belinurus reginae* Baily and *E. anthrax* Woodward. The genal spines, which are not well shown in our specimen, are developed from the sides of the prosoma as in *E. anthrax*. The posterior margin of the glabella is marked by two short neck spines, on either side of which the margin of the prosoma slopes anteriorly and meets the lateral margin of the prosoma in the genal spines.

The characters of the glabella are not well shown, and only a faint trace of the two lobes can be distinguished.

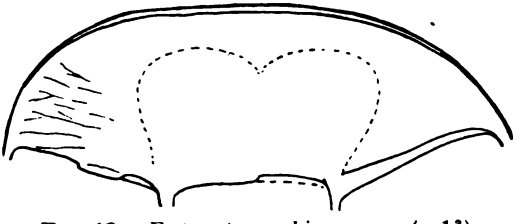

FIG. 13.—*Euproops meeki* sp. nov. (x 1¾).

In *E. meeki* the genal spines appear to curve posteriorly as in some other species of *Euproops*, and in this character it differs from *E. anthrax*, in which the genal spines are outwardly directed. Our specimen also differs from *E. anthrax* in the shape of the prosoma, it being more elliptical than in that species. Unfortunately the thoracetron is missing and it is also impossible to compare the glabella of this form with that of other species of *Euproops*.

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The specimens, the holotype of this species and its counterpart, are preserved in the Museum of Practical Geology, and are numbered 48528 and 48529 respectively.

Euproops cambrensis sp. nov.

Fig. 14.

A well-preserved specimen of *Euproops* was collected by Mr. T. Llewelwyn in dark grey shale from the roof of a seam 15 yards above the New Seam (which is considered to be the equivalent of the Gellideg Seam), at the Ocean Colliery, Blaengarw, north of Bridgend. Associated with it are a number of plant fragments, including *Cordaites sp.*

Dimensions.—

Length of prosoma, 19 mm.
Breadth of prosoma across the genal spines, 41 mm.
Length of glabella, 13·5 mm.
Breadth of glabella near the orbits, 12 mm.
Breadth of glabella at the posterior margin of the prosoma, 9·5 mm.
Length of genal spine (preserved), 11 mm.
Estimated length of neck spines, 11·5 mm.
Distance between neck spines near their extremities, 15 mm.
Length of thoracetron, 19 mm.
Estimated breadth of thoracetron at its anterior margin, 35 mm.
Breadth of marginal fringe, 5 mm.
Breadth of central axis near cervical border, 4·5 mm.
Breadth of one thoracic segment, 3·5 mm.
Length of mesosoma, 13 mm.
Length of metasoma, 6 mm.
Length of telson, unknown.

The prosoma is a little more than twice as broad as long; the anterior margin is only very gently curved for half the breadth of the prosoma, curving smoothly backwards into the genal spine. The frontal doublure is strongly marked as in *Euproops anthrax* Woodward and *Belinurus reginae* Baily. The posterior margin of the prosoma on either side of the neck spines slopes anteriorly to meet the inner border of the genal spines at an angle of about 90 degrees. The genal spines are broad. The border of the prosoma is slightly raised to form a narrow raised rim, which continues along the anterior half of the genal spine when it becomes faint and finally disappears about 2 millimetres from the end of the spine.

The glabella is well shown; it is quadrangular in shape, and is more than two-thirds the length of the prosoma. It is divided into two distinct lobes by means of a well defined median ridge, which is nearly as wide as the axis of the thoracetron. The position of the eyes cannot be determined in the specimen. The lateral margins of the glabella are slightly re-entrant, the posterior portion being produced to form long, and slightly diverging neck spines which extend almost to the posterior margin of the mesosoma.

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There are traces of punctation on the anterior portion of the glabella and on the surface of the prosoma near the glabella margin. The front of the prosoma is, like the thoracetron, finely granular or pustulose.

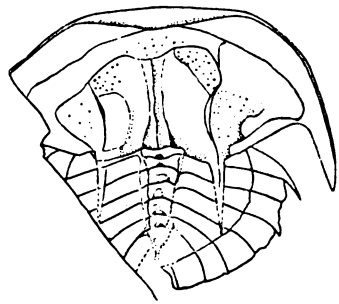

FIG. 14.—*Euproops cambrensis* sp. nov. (nat. size).

The thoracetron is distinctly trilobed, and is nearly semi-circular in outline. The central axis is well marked and is narrow in proportion to the prosoma. The thoracetron is composed of six nearly equal coalesced segments, the ridge and furrow of each can be seen on the central axis. Each segment is produced into a spine which extends across the membraneous margin of the thoracetron. Six of the spines are strongly marked, and a seventh, an extension of the abdominal or metasomatic portion, is less clearly shown. These marginal spines appear to have been of almost equal length and to project backwards for about four millimetres beyond the margin of the membrane.

The abdomen or metasoma is not clearly shown in the specimen; the telson is not preserved.

The presence of tubercles along the central axis is indicated; the one on the first segment being well marked, and a broad base of a large tubercle is indicated near the point of insertion of the telson. The entire surface of the thoracetron is covered with small granules.

E. cambrensis can be distinguished from other species of *Euproops* by the shape of the prosoma. It most closely resembles that of *E. amiae* Woodward, but it differs from that form in that the genal spines are directed more posteriorly. It also differs in the form of the glabella, that of *E. amiae* having traces of segmentation and not being completely divided by a median ridge, while the axis of the thoracetron in *E. cambrensis* is narrower than in *E. amiae*. The membraneous margin of the thoracetron, however, is wider than in *E. amiae*, the species approaching in this character to *Prestwichianella rotundata* (Prestwich), from which it differs in many important features.

The holotype of this species has been presented to the Geological Department, National Museum of Wales (No 29,198, G1.).

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Euproops scheeleana (Ebert)

A specimen of a Xiphosurid was collected by Mr. T. H. Rowlands, M.Sc., from the roof of the Six Feet Seam at the Mynydd Newydd Colliery, Swansea.[1] It is preserved in a black shale containing numerous specimens of *Anthracomya* and *Lepidophyllum*.

Unfortunately, the glabella is in a poor state of preservation, but the shape of the head-shield, the character of the genal spines, and the wide marginal fringe of the thoracetron leaves little doubt as to its identity with Ebert's species.

This specimen is in the collection of the University College of Swansea.

Euproops cf. *anthrax* (Prestwich).

Three fragments of head-shields of *Euproops* were collected by Mr. T. H. Rowlands, M.Sc., in a small block of grey shale from a horizon near the Three Feet Seam, at the Copper Pit Colliery, Morriston, near Swansea.[2]

In one instance, the specimen represents a fragment of the prosoma showing the genal spine, a well-preserved glabella, and a small fragment of the thoracetron. This example agrees with *Euproops anthrax* (Prestwich) in the double frontal border of the cephalon and in the form of the hinder portion of the prosoma, which slopes anteriorly, so that the genal spines appear to rise from the centre of each side of the head. In our specimen, however, the genal spines are not so outwardly directed as in *Euproops anthrax*.

The glabella, which is not so quadrangular as in other species of *Euproops*, is divided into two distinct lobes by means of a median ridge. Unfortunately the position of the eyes cannot be determined. The Morriston specimen agrees closely with a form figured by Dr. H. Bolton as *E. anthrax* from the Kent Coalfield.[3]

The two other fragments are undoubtedly related to the specimen here described.

These specimens have been presented to the University College of Swansea.

Euproops sp. (Cf. *E. anthrax* (Prestwich))

Fig. 15.

A fragment of the head-shield of a Xiphosurid was obtained by Mr. D. Davies, F.G.S., from a black shale from the roof of the Swansea Four Feet Seam, at the Mountain Colliery, Gorseinon. It was associated with numerous leaves of *Cordaites*.

[1] Rowlands, T. H., ' The Correlation of the Coal Measures in the Western Portion of the South Wales Coalfield. Part III—The Upper Part of the Pennant Series of the Swansea District.' *Proc. South Wales Inst. Eng.*, vol. xli, 1925, p. 263.

[2] Rowlands, T. H., *ibid.*

[3] Bolton, H., ' The Fauna and Stratigraphy of the Kent Coalfield.' *Trans. Inst. Mining Engineers*, 1915.

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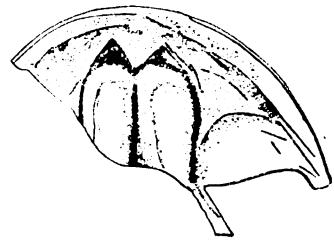

FIG. 15.—*Euproops sp.*
Cf. E. anthrax (nat. size).

This specimen appears to agree with *E. anthrax* in the character of the genal spines, which arise from the centre of each side of the head-shield. The glabella is well-shown, but since this is not exhibited in the type species of *E. anthrax* a comparison cannot be made. The glabella differs in shape, however, from other species of *Euproops*, being less quadrangular. In this character it shows an affinity with *Prestwichianella*.

The specimen is preserved in the National Museum of Wales and is registered 03605,27,177,G3.

Notes on other fragments which are referred to Euproops.

Several incomplete examples which appear to have closer affinities with *Euproops* than with *Prestwichianella* have been obtained at several localities, but in all cases the fragmentary character of the specimens renders it impossible to place them with certainty.

One specimen, a portion of the thoracetron, showing the long spines of the segments projecting beyond the marginal fringe, was collected from black shales associated with the Graigola Seam, east of Drummau Hill, near Neath. A number of specimens of *Leaia leidyi* were found in the same shales. In some respects the characters of the fragments suggest affinities with Meek and Worthen's species of *E. danae*. The specimen is preserved in the Museum of Practical Geology and is registered 20768.

Two examples, also in the Museum of Practical Geology, registered 48527 and 48530, were found in the roof shales of the Mynyddislwyn Seam at the Gwernau Level, Maesycwmmer. One, 48527, is a poorly-preserved, incomplete cephalon, and 48530 shows a portion of the thoracetron.

From the same horizon as the above, a fragment of the prosoma, somewhat crushed, was obtained at the Old Gelligaer Colliery, half a mile S.E. of Llancaiach Station. It was associated with *Leaia leidyi*, var. *salteriana* Jones, ostracods, *Anthracomya phillipsi* Will. and an abundant flora. This specimen is also in the collections of the Museum of Practical Geology, registered 48531.

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Euphoberia sp. nov.?

It seems also appropriate to notice in this paper the presence of the Myriapod, *Euphoberia* in the Coal Measures of South Wales. The specimen was collected by one of the writers in 1902, and was subsequently identified by Mr. E. T. Newton, F.R.S., as *Euphoberia armigera* Meek and Worthen. Recent studies of the fossil, however, lead us to regard it as belonging to a distinct but closely allied species. At the same time, the preservation of the specimen would hardly justify the description of it as a new species until additional material is available for study.

The specimen measures 35 mm. in length. The dorsal segments are badly crushed, and it is difficult to decipher the ornament or to ascertain the shape and size of each segment. The ventral segments, however, are well shown. These appear to be 1·5 mm. in breadth and 2 mm. in length, each carrying weakly-jointed legs 4 mm. long. The edge of each segment is slightly raised, and under a lens, each presents the appearance of those which are found in *Euphoberia granosa* Scudder.[1]

The Myriapod was obtained from shales associated with the Graigola Vein at the Clydach Merthyr Colliery, 500 yards W.S.W. of Pen-y-banc farm, Clydach, and was recorded as *E. armigera* in the memoir on the geology of the South Wales Coalfield, pt. vii. It was found in association with *Prestwichianella nitida, Euproops graigolae* and other arthropod remains.

[1] Scudder, S. H., 'The Fossil Insects of North America,' vol. i, 1890, pl. 9, fig. 22.

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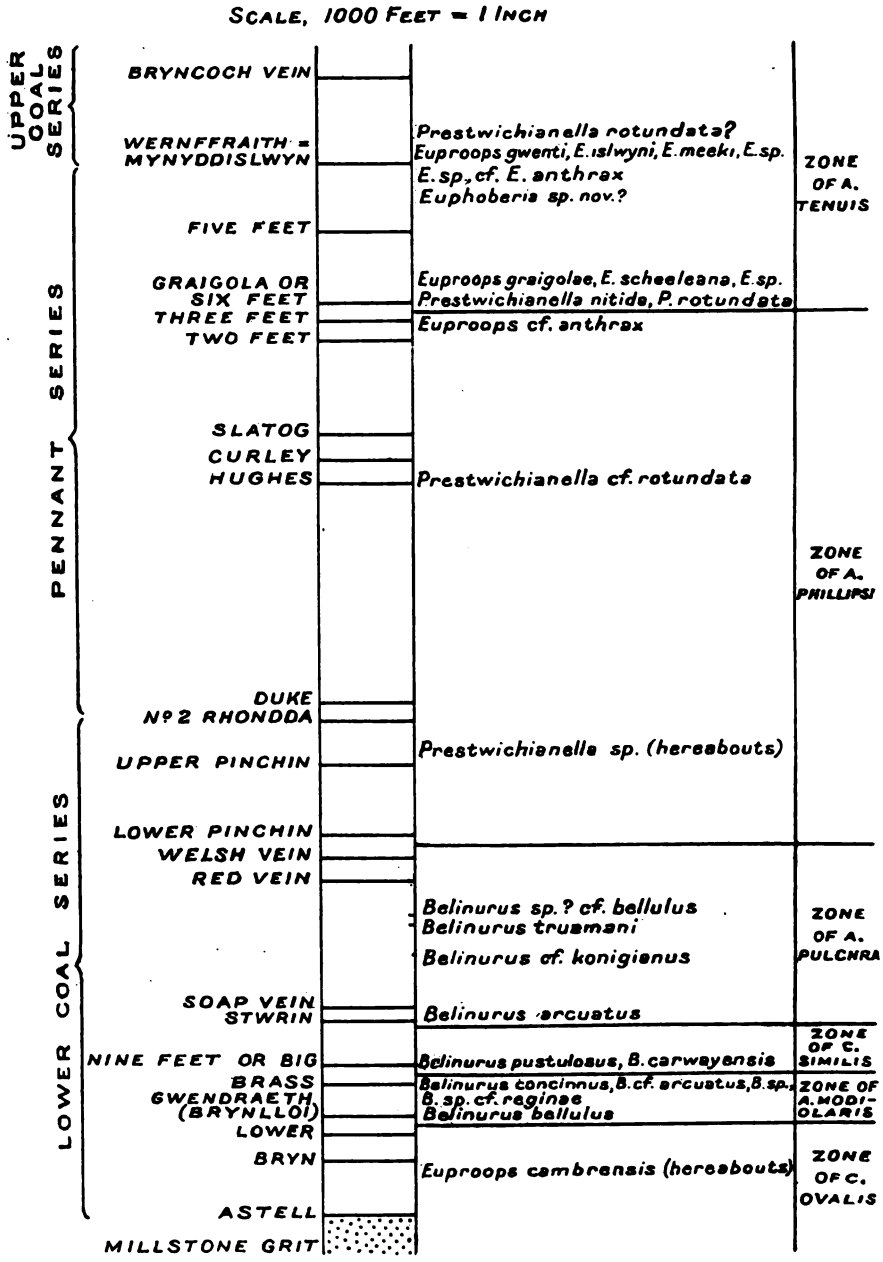

FIG. 16—*Table showing vertical range of* Belinurus, Euproops, *and* Prestwichianella *in South Wales.*

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VII.—'NIPS' AND 'ROCK-RIDERS' IN THE WEST CUMBERLAND COALFIELD

By T. Eastwood, A.R.C.Sc.

Text-figures 1 and 2

Accounts of the Coal Measures, including the sequence and the correlation of the coal seams, of West Cumberland have appeared in previous 'Summaries of Progress.'[1] It may be stated briefly, however, that the Cumberland Coal Measures consist of an upper more or less barren and arenaceous series, styled the Whitehaven Sandstone, and a lower more argillaceous group containing a large number of coal seams, which is referred to as the Productive Measures. This lower group is about 1,000 feet in thickness and the seams usually mined are grouped in the middle 500 feet, the most important—the Main Band—occurring about midway. The principal seams in upward succession are: the Six-quarters, the Little Main, the Yard, the Main Band, the Bannock Band and the Ten-quarters. All have received synonyms in different parts of the area.

In common with other districts the continuity of the coal seams is liable to interruptions from various causes. Some of these may be referred to accidents of deposition owing to inequalities of the platform on which they were laid down; *e.g.*, many of the chance seams were probably deposited in small basins. Other interruptions are due to faulting long subsequent to the formation of the coal. Of these perhaps Cumberland has more than a fair share. There remain, however, certain interruptions which are due to agents operating soon after the formation of any particular seam. Of these the most important are termed 'nips,' while those of lesser importance are 'rock-riders.' In nips the coal is absent 'in plan,' while with rock-riders it is removed 'in elevation.' Both apparently depend on the presence of sandstone not far above the coal.

The nips of West Cumberland are the equivalent of the 'wash-outs,' 'wants,' or 'dumb-faults' that are met with in other coalfields such as Warwickshire and Yorkshire, but in our area the coal is seldom removed along well-defined channels that are referable to stream courses of Coal Measure times. On the other hand, although long narrow nips such as are attributed to stream action do occur, by far the larger area of coal is removed in haphazard fashion, and must be referred, in general, to the action of shifting currents in the deltas bringing down sands which ultimately formed the roof sandstones. Their distribution is shown on the map (Fig. 1).

Nips, as a rule, are first encountered in the top part of a seam and when followed along are found to descend with varying rapidity

[1] For 1921 (1922), 1924 (1925) and 1925 (1926).

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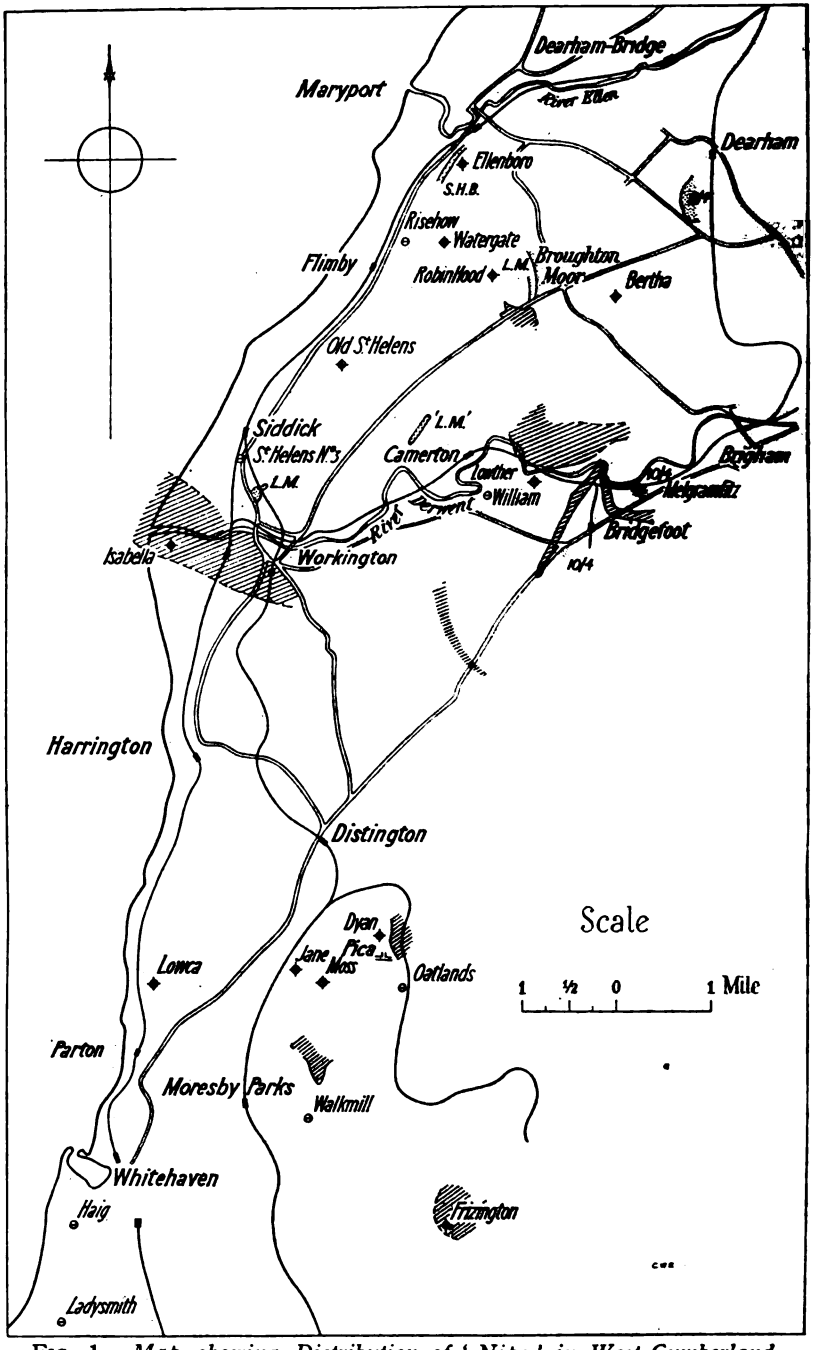

FIG. 1.—*Map showing Distribution of 'Nips' in West Cumberland.* Shaded areas refer to Main Band; stippled areas to other seams. S.H.B.=Senhouse High Band; 10/4=Ten-quarters Coal; L.M.=Little Main; 'L.M.'=Camerton Little Main.

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until the greater part, or all, of the seam is removed. In some cases, however, within the limits of completely nipped ground, all the coal is not lost. In the Moresby area, for instance (Fig. 2), where

FIG. 2.—*Diagrammatic section of nipped ground in the Main Band, Walk Mill Pit, Moresby.*

Showing rock-riders, partial and complete nips and duplication of the seam.

nipped ground was met with in the Main Band, the seam was repeatedly cut out by the roof sandstone, but irregular 'islands' of coal remained, in some cases the lower part of the seam—including the characteristic band of cannel—being left, in others the entire thickness. Such occurrences may be regarded as more or less normal, but on the edges of some of the nips the seam was duplicated. This repetition was not due to overfolding, for the cannel in every case occurred in the lower part of both seam and duplicate. Furthermore, no crushing or slickensiding, such as one would expect in the event of overthrusting, was observed.

Prof. P. F. Kendall[1] has suggested that the duplication of seams adjacent to nipped areas is due to lurching of the ill-consolidated material under seismic stresses. This is probably true in many instances when 'wants' occur along well-defined lines, but to account for the irregular occurrences at Moresby it is suggested that large masses of coal material were rafted from their bed by strong floods and stranded on other portions which resisted the onslaught of the waters.

Other areas in which the Main Band has been removed include Pica, where a nip was met with east of Dyan Pit. This probably extends for a considerable distance in an easterly direction. To the west, between Pica and Distington, a smaller one occurs around Moss Pit and the seam is thinner than usual at Jane Pit.

Farther east again, at Frizington Colliery, the Main Band is partially nipped to the south-west of the shaft and appears to be entirely wanting for some distance to the north and north-east.

In the ground underlying the Derwent valley large areas of the Main Band have been removed by penecontemporaneous erosion. The nips here belong to two types (1) ill-defined like that at Moresby, and (2) well marked 'wants' of linear character such as are attributed to stream erosion. (It is noteworthy, though the circumstances may be purely fortuitous, that it is in this area that the Main Band begins to split up into the Cannel, Metal and Crow Bands.)

[1] 'On "Wash Outs" in Coal Seams and the effect of Contemporary Earthquakes,' *Abstract Proc. Geol. Soc.*, No. 1031, Jan. 17, 1919, pp. 28-31.

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A large area of the first type occurs near the mouth of the Derwent and is known as the 'Great Nip.' In the shaft of Isabella Pit the coal is absent, but to the south-west the lower part makes its appearance and the seam gradually regains its normal character. The coal is also absent in most of the old pits in the northern part of Workington. Farther north nipped ground was entered in the workings south-west of St. Helens No. 3 Pit, Siddick. If this be continuous with that of Isabella Pit the 'Great Nip' of Workington must be about three-quarters of a mile in breadth and over a mile in length.

On the east side of Workington the Main Band horizon is thrown out by the 'Great Upcast Fault.' Farther east, however, near William Pit, the normal seam is present but is cut out by sandstone towards outcrop south of the William Pit workings. Continuing in an eastward direction we find the nips of Lowther and Melgramfitz pits. Those south of the Derwent are of the second or linear type and may unite as shown on the map (Fig. 1). That north of the river belongs to the first type and at its western end may be more extensive than indicated.

North of the Derwent valley small nips are known in the Main Band at Old St. Helens; they appear to be more extensive (as one would expect) in the upper or Metal Band portion of the seam. A still larger one occurs on Broughton Moor. Sections south of Robin Hood Pit show successive portions of the Cannel Band (here the most important seam) cut out by the freestone roof until the seam is entirely wanting.

Nips do not appear to be so extensive in seams other than the Main Band, but, in addition to smaller occurrences, the following may be noted.

The Little Main, one of the most regular seams in the coalfield, usually has a roof of blue mudstones, but in two of the places where a sandstone roof is locally developed—Siddick and Broughton Moor—nips are present. At Camerton a seam known as the Little Main, but lying between the true Little Main and the Six-quarters, is nipped; and the Ten-quarters is locally cut out by its freestone roof at Melgramfitz, at Bridgefoot, and south-east of Dearham. The Senhouse High Band, a coal occurring in the Whitehaven Sandstone Series, is subject to nips in the Ellenborough workings.

Next to be considered are the narrow, wall-like, more or less vertical ribs of sandstone known as rock-riders. These vary from an inch or less to 2 feet or so in thickness. Their connexion with the roof sandstone was noted in the nipped ground at Moresby. There, as the nips were approached, joints in the coal were enlarged and filled with sandstone identical, and in some cases continuous, with that forming the roof. In some instances the rock not only penetrated the full thickness of the seam but spread out along its floor forming small bars (Fig. 2). In the few instances directly

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observed the bedding in the sandstone forming the ribs was not well defined and the rock split irregularly.

It is evident that at Moresby the infilling took place soon after the deposition of the Main Band Coal and probably accompanied the formation of the nips, *i.e.* rents caused by the rafting of adjacent material were filled with sand carried along by the flood waters, bars or buttresses at the base being made by the rocking of the seam under impact of the flood.

In other cases, however, where ribs are not accompanied by nips or wash-outs, as at Whitehaven, the formation of riders may have been of somewhat later date. In such cases it is necessary to be certain of the age of the infilling material. Dr. A. Gilligan[1] mentions cases at Ladysmith Pit, Whitehaven, where a dyke passes through not only the Main and the Bannock Bands but also the 54 feet of intervening strata. He ascribes the infilling material to the Whitehaven Sandstone. While perhaps not impossible it is somewhat difficult to conceive of a crack of less than ten inches in width persisting and keeping open through the 460 feet of mixed shale and sandstone measures that intervene between the base of the Whitehaven Sandstone Series and the Main Band. In material recently submitted by Mr. T. S. Durham from a rock-rider in the Main Band of Haig Pit, Whitehaven, there is no doubt whatever that we are dealing not with Whitehaven Sandstone but with sandstone of the Productive Measures.

Such riders, however, which are unaccompanied by nips of the Moresby type, may well be due to the infilling of cracks—caused by earthquakes—by unconsolidated sediments, as suggested by Dr. Gilligan.[2]

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[1] 'On the Sandstone Dykes or Rock-Riders in the Cumberland Coalfield,' *Abstract Proc. Geol. Soc.*, No. 1031, Jan. 17, 1919, pp. 31-36. See also 'Description of a Group of Dykes, termed Riders, discovered in the Whitehaven Colliery,' by Williamson Peile, *Trans. Nat. Hist. Soc. Northumb. and Durham*, vol. I, 1831, pp. 160-4.

[2] *Op cit.*, p. 32.

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VIII.—The Occurrence of a Rhyolite between the Ordovician and Pre-Cambrian Rocks near Habberley, Shropshire

By Talbot H. Whitehead, M.Sc., A.R.C.Sc.

Text-figures 1 and 2.

Pontesford and Earl's Hills (generally alluded to in geological literature simply as 'Pontesford Hill') form the western limit of a somewhat steep-sided valley through which the Habberley Brook flows from Habberley to Pontesford.

Pontesford Hill is formed of volcanic rocks of pre-Cambrian age (Western Uriconian of Callaway[1]) reinforced by basic intrusions.[2] The wooded eastern side of the valley is occupied by grits and conglomerates belonging to that part of the pre-Cambrian sequence known as the Western Longmyndian (Wentnor Series).[3] The middle part of the valley is underlain by grey shales of Ordovician age. These are probably faulted against the Uriconian rocks of Pontesford Hill; but rest unconformably upon the pre-Cambrian rocks towards the east.

Of the pre-Cambrian rocks of Pontesford Hill it is sufficient for the present purpose to mention that they include lavas and fragmental rocks both of acid and of relatively basic composition. These form a stratified series into which dolerite sills have been intruded.

At and north of the Lyd Hole, where, 300 yards south-east of Earlsdale, the Habberley Brook descends a series of small falls, volcanic rocks similar to those of Pontesford Hill are exposed. These include, at the Lyd Hole itself, a rhyolite, and farther north, basic rocks of which some are pyroclastic. Immediately south of the Lyd Hole the Longmyndian rocks appear to succeed the rhyolite without any break. The junction has been interpreted as a fault[4]; but for reasons into which it is not germane to the present purpose to enter, it is believed that this is improbable. On the other hand it has been supposed that an intrusive relation subsists.[5] This interpretation, even if applicable to the rhyolite, is evidently inadmissible as far as the associated pyroclastic rocks are concerned.

The Longmyndian rocks of the area with which this paper deals consist of grits with two beds of conglomerate. Both grits and conglomerates contain much material of volcanic derivation. The dip is to east-south-east at 60 to 75 degrees, and the thickness

[1] *Quart. Journ. Geol. Soc.*, vol. xxxviii, 1882, p. 119; and vol. xlii, 1886, p. 481.

[2] See Boulton, W. S., 'The Igneous Rocks of Pontesford Hill, Shropshire.' *Quart. Journ. Geol. Soc.*, vol. lx, 1904, p. 450.

[3] Blake, J. F., *Quart. Journ. Geol. Soc.*, vol. lxvi, p. 386; and C. Lapworth in 'Geology in the Field' (*Geol. Assoc. Jubilee Vol.*), 1910, p. 748.

[4] Callaway, C., *op. cit.*, p. 121.

[5] Blake, J. F., *op. cit.*, pp. 402, 403.

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of rock between the ' top ' of the Lyd Hole rhyolite and the ' base ' of the ' higher '[1] conglomerate is estimated as 1,250 feet.

The Ordovician rocks are shown as ' Lingula Flags ' on the Old Series map (Sheet 61) of the Geological Survey. The first published note of their Ordovician (' Lower Caradoc ') age appears to be due to C. Callaway.[2] Collections made during the recent six-inch survey of the area have resulted in the following list,[3] in which the graptolites have been named by Dr. G. L. Elles and the other fossils by Mr. J. Pringle :—

Climacograptus antiquus *Lapw.*, (1), (2), (3).
,, bicornis *Hall*, (3).
,, caudatus *Lapw.*, (1).
? ,, wilsoni *Lapw.*, (2).
Cryptograptus tricornis (*Carr.*), (3).
Diplograptus (Mesograptus) foliaceus *Murch.*, (1).
,, ,, multidens *E. & W.*, (2), (3).
,, (Orthograptus) truncatus *Lapw.*, (2).
,, ,, *var.* intermedius *E. & W.*, (1).
Orthis (Dalmanella) *cf.* testudinaria, *Dalm.*, (1).
Trinucleus concentricus (*Eaton*), (1).

These shales may therefore be regarded as lying near the base of the Caradocian.[4]

The unconformable relation of the Ordovician rocks to the pre-Cambrian is clearly brought out by mapping. East of Radlith Wood they rest upon the ' lower ' of the two conglomerates referred to above (p. 120). Traced south-westward the base passes across rocks ' lower ' in the pre-Cambrian sequence until, in the bank of the Habberley Brook south-east of Earlsdale, it rests upon the volcanic rocks of Uriconian type. Here the conglomeratic basement bed is exposed, overlain by fossiliferous shales (Locality 2 of fossil-list). The actual base is not seen again for over half a mile south of this locality, though indications of the shales can be found at several places. Near Earlsdale the shales dip to north-west at 45 degrees. The basement bed is next exposed 1,290 yards south of Earlsdale (or approximately a mile north-east of Habberley), where a ford across the Habberley Brook is shown on the six-inch map

[1] The expressions ' top,' ' base,' ' higher ' are here used merely in relation to the observed local dip, and without prejudice to the question whether the present order is the original one.

[2] *Op. cit.*, p. 121.

[3] Localities and registered numbers : (1) East bank of Habberley Brook, 500 yds. north of the Lyd Hole ; D. 571–586, T.W. 459–464, 477–480. (2) East bank of Habberley Brook 150 yds. north of the Lyd Hole ; D. 587-602, T.W. 465. (3) West bank of Habberley Brook, 300 yds, west of Oaks Lodge (near " ford ") ; D. 603–623, T. W. 466, 467.

[4] Dr. Elles, in naming the graptolites, added the note that they indicated ' the junction of the Caradocian and Llandeilian (zone of *Mesograptus multidens* and *Climacograptus wilsoni*).' The practice of the Geological Survey has been to place the summit of the Llandeilian somewhat lower, at the base of the zone of *Nemagraptus gracilis*. See ' The Country around Carmarthen ' (*Mem. Geol. Surv.*), 1909, p. 39 ; and ' The Country around Haverfordwest ' (*Mem. Geol. Surv.*), 1914, p. 40.

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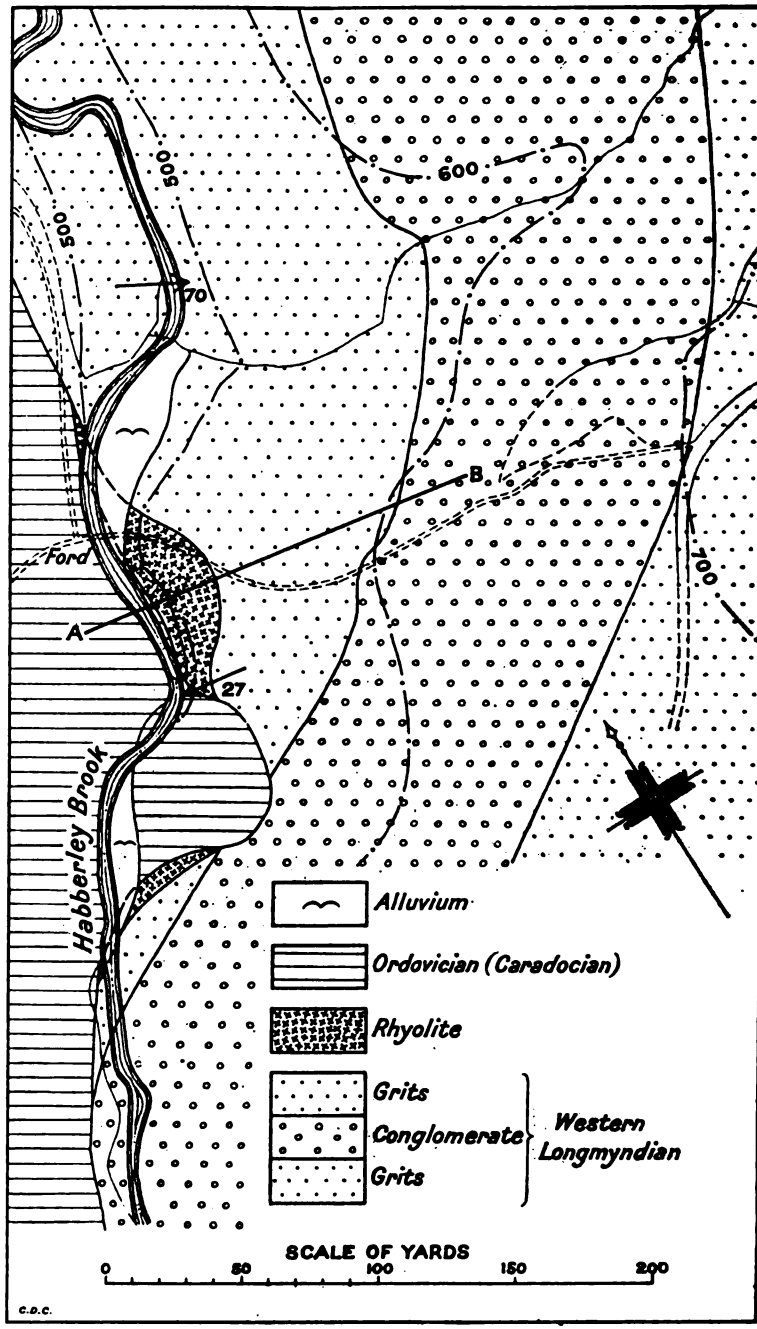

FIG. 1.—*Sketch-map of Habberley Brook, west of Oaks Lodge and about ¾ mile south of Earlsdale.*

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(Shropshire 40 S.E. ; see also Fig. 1). Here the shales which yield fossils (Locality 3 of fossil-list), pass down into sandy beds and these into pebbly grit and conglomerate (Fig. 2). The dip of the sandy beds is to west at 27 degrees. Purple Longmyndian grits are exposed some 50 yards north of the ford. These lie in the ' upper ' half of the beds separating the two Longmyndian conglomerates (see above, p. 120).

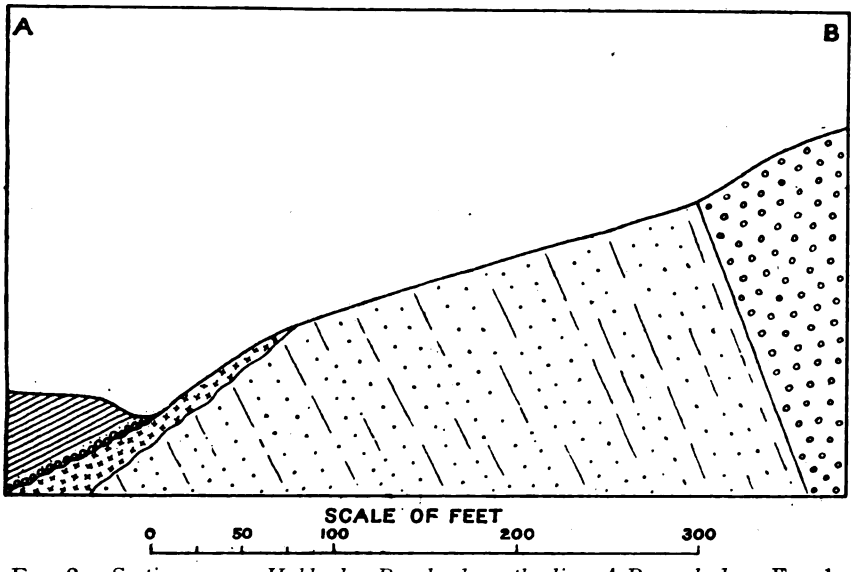

FIG. 2.—*Section across Habberley Brook along the line A-B marked on* FIG. 1.

Where exposed, however, the base of the Ordovician rests, not upon the Longmyndian grits, but upon the rhyolite that is the subject of this paper. This rock has an irregular surface with rounded protuberances that may stand out as much as four feet above the average level. The basal Ordovician conglomerate wraps round these protuberances and is moulded into the hollows between them. The conglomerate contains unmistakable pebbles of the rhyolite in addition to others of quartz and quartzite. Some of the rounded masses of rhyolite, isolated by the conglomerate from the main portion of the rock, may actually be boulders.

The rhyolite is of a dark grey or pinkish colour. The greater part of it shows conspicuous flow-banding. The banding is in places much contorted, but seems to have an average direction not far removed from parallelism with the strike of the Ordovician rocks. The pinkish colour is confined to narrow bands, and it is where these are numerous and close together that the rock, as a whole, assumes that hue. Even narrower white streaks are also to be seen. The microscope[1] shows that the streaked or banded appearance is due to

[1] Slices E. 14344 and E. 14532 in the Survey Collection.

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the alternation (in bands of a millimetre or upwards in thickness) of very fine with relatively coarse aggregates of quartz resulting from devitrification. Streaks of still coarser aggregates probably represent secondary or migrated silica, and are presumably the white streaks seen in hand specimen. Colour differences are probably due principally to the differential distribution of granular or cloudy material, possibly ilmenite, which is more abundant in the coarser bands. Pale chloritic material is more or less evenly distributed. Phenocrysts are rare, and consist of an occasional corroded crystal of what is probably oligoclase, and a few small needle-like crystals of similar composition.

In considering the age of this rhyolite, the possibility that it is pre-Cambrian must be examined. In this connexion it may, firstly, be noted that the rock differs somewhat from the rhyolites of Pontesford Hill and that of the Lyd Hole. The differences, it is true, lie more in the colour and appearance in hand specimen than in the microscopic characters, in which it has, naturally, points in common with the other rhyolites. It is, however, further dissociated from the Lyd Hole rhyolite by the fact that the parts of the Longmyndian sequence with which the two rocks are respectively in contact are separated by about 1,200 feet of strata (p. 121). There is no evidence of faulting that could account for this fact. On the contrary the Longmyndian rocks, within the relevant area, maintain a very regular strike and show no signs of more than trivial dislocations. The actual contact of the rhyolite with the Longmyndian grits is unfortunately nowhere exposed; but the form of its outcrop precludes the idea that the igneous rock is intercalated amongst the pre-Cambrian sediments, either as a flow or as any form of intrusion having a simple relation to their dip and strike. The manner in which the base of the rhyolite mounts the steep eastern bank of the Habberley Brook indicates, in fact, a sheet-like body dipping towards the west and therefore strongly discordant with the pre-Cambrian rocks. It is believed, therefore, that the possibility of its being itself pre-Cambrian may be dismissed; and that it may be regarded as lying unconformably up on the Longmyndian, and, in its turn, unconformably overlain by Caradocian sediments (see Fig. 2).

Volcanic rocks being rare in the Cambrian system the strong presumption is that this rhyolite is of Ordovician age. It has been shown (p. 121) that the upper limit of possible age is low in the Caradocian, or, more precisely, the zones of *Mesograptus multidens* and *Climacograptus wilsoni*, which here appear to be inseparable. It is, therefore, possible that the rhyolite is comparable with some part of the Conway volcanic series, which is overlain by shales belonging to the zone of *Climacograptus peltifer*,[1] or of the lower part of the Snowdon volcanic rocks, which " appear to range from

[1] Elles, G. L., ' The Relation of the Ordovician and Silurian Rocks of Conway (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxv, 1909, p. 169 (see p. 172).

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the higher part of the zone of *Nemagraptus gracilis* . . . to the zone of *Dicranograptus clingani*."[1] In Shropshire itself, however, the highest Ordovician volcanic rocks lie above the horizon of the shales that rest upon the Habberley Brook rhyolite. The latter is therefore hardly likely to be later in age than the lower volcanic group (the Stapeley Group) of the Shelve area, which rests upon shales with *Didymograptus bifidus*.[2] The Stapeley Group includes lavas, which, however, have the composition of hypersthene or augite andesites.[3]

The grey shales of the valley east of Pontesford Hill represent part of that period of quiet deposition that, in the west of England and Wales, intervened between the Arenig and the Llandeilo-Caradoc outbursts of volcanic activity. In Shropshire this period was one of transgression, and it is interesting to find that the sedimentary transgression was apparently anticipated, perhaps in Arenig times, by a flow of lava.

[1] Williams, H., 'The Geology of Snowdon (North Wales),' *Quart. Journ. Geol. Soc.*, vol. lxxxiii, 1927, p. 346 (see p. 391).

[2] Lapworth, C., in 'Summary of Progress' for 1915 (*Mem. Geol. Surv.*), 1916, p. 37.

[3] Watts, W. W., 'The Geology of South Shropshire,' *Proc. Geol. Assoc.*, vol. xxxvi, 1925, p. 341.

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